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Refuse of Fermentation Brines in the Cucumber Pickling Industry

Pickle Packers International, Inc, St Charles, IL

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CUCUMBER PICKLING INDUSTRY

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-CI) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report shows the results of a commercial evaluation of the reuse of "spent brine" in the cucumber pickling industry. It appears that the cucumber pickling industry can economically recover and reuse most of the fermentation brines generated in tank yards. This can lead to important reductions in waste generation in this industry without significant changes in the quality of the products produced. As a result, this report should be of interest to the processors in this industry and environmental regulatory agencies. For further information on this project contact the Food and Wood Products Branch, Industrial Pollution Control Division, Industrial Environmental Research Laboratory-Cincinnati.

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ABSTRACT

The project evaluated on a commercial scale the technological and economic feasibility of recycling spent cucumber fermentation brine. Two brine treatment procedures, heat treatment and chemical treatment, were used. The results showed that brine recycling was practical on a commercial scale. Either brine treatment procedure resulted in salt stock which were equivalent in quality to control cucumbers.

Studies were conducted to determine the adequacy of the brine treatment procedures employed. The data confirmed that a heat treatment of 175°F for 30 sec. was sufficient to assure inactivation of pectinases from molds found to be common on cucumber fruits and flowers. For effective chemical treatment a brine temperature of 72°F or higher was required. In addition, the pH had to be maintained at 11.0 or higher for at least 36 hr to assure 99% inactivation of pectinases from the molds which were investigated.

An economic evaluation of the recycling procedures showed a small net savings for the heat treatment procedure and a small net cost for chemical treatment. Selection of the process for a particular plant will depend upon the local conditions.

This report was submitted in fulfillment of Grant S-803825 by Pickle Packers International, Inc., under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers a period from May, 1975 to December, 1977; data collection was completed as of October, 1977.

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CONVERSION FACTORS AND METRIC PREFIXES^a

CONVERSION FACTORS

To convert from	to	Multiply by
Degree Fahrenheit (^o F)	Degree Celsius (^o C)	$t^o_C = 0.56 (t^o_F - 32)$
inch (in)	metre (m)	2.54×10^{-2}
foot (ft)	metre (m)	3.048×10^{-1}
gallon (gal)	metre ³ (m ³)	3.784×10^{-3}
bushel (bu)	metre ³ (m ³)	3.524×10^{-2}
3.8 gal/bu	$0.408 \text{ m}^3/\text{m}^3$	1.0
grain (gr)	kilogram (kg)	6.48×10^{-5}
ounce (oz)	kilogram (kg)	3.11×10^{-2}
pound (lb)	kilogram (kg)	4.536×10^{-1}
gallons per minute (gal/min)	metre ³ /second (m ³ /s)	6.308×10^{-5}
ounces per gallons (oz/gal)	kilogram/metre ³ (kg/m ³)	8.218
pounds per ton (lb/ton)	kilogram/kilokilogram (kg/kkg)	4.643×10^{-1}
pounds per 1000 pounds (lb/1000 lb)	kilogram/kilokilogram (kg/kkg)	1.0
tons per year (ton/yr)	kilokilogram/year (kkg/yr)	9.074×10^{-1}
gallons per ton (gal/ton)	metre ³ /kilokilogram (m ³ /kkg)	4.17×10^{-3}

<u>To convert from</u>	<u>to</u>	<u>Multiply by</u>
pounds per gallon (lb/gal)	kilogram/metre ³ (kg/m ³)	1.1984×10^2
pounds per 1000 gallons (lb/1000 lb)	kilogram/metre ³ (kg/m ³)	1.1984×10^{-1}
cost per pound (\$/lb)	cost/kilogram (\$/kg)	4.536×10^{-1}
cost per gallon (\$/gal)	cost/metre ³ (\$/m ³)	2.642×10^2
cost per 1000 gallon (\$/1000 gal)	cost/metre ³ (\$/m ³)	2.642×10^{-1}
cost per ton (\$/ton)	cost/kilokilogram (\$/kkg)	1.102

METRIC PREFIXES

<u>Prefix</u>	<u>Symbol</u>	<u>Multiplication factor</u>	<u>Example</u>
kilo	k	10^3	2 kg = 2×10^3 grams
centi	c	10^{-2}	2 cm = 2×10^{-2} metre

^aStandard for Metric Practice. ANSI/ASTM Designation: E 380-76^E, IEEE Std 268-1976, American Society for Testing and Materials, Philadelphia, Pennsylvania, February 1976. 37 pp.

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SECTION 1

INTRODUCTION

Per capita pickle consumption in the United States has shown steady increases since 1930 from 1.07 kg to 3.75 kg in 1976. There are two major classes of cucumber pickles, fresh pack and process pack. Fresh pack products are prepared by processing fresh cucumbers directly into final products. The process pack requires initial fermentation of cucumbers, storage at high salt concentrations, and subsequent desalting prior to processing into consumer or institutional products. In 1975 the process pack operation utilized 206,000 metric tons of green stock or 64% of the green stock purchased by processors (1). This distribution of product utilization makes the tank yard a major source of waste in the industry. Kirk (2) reported that spent brine accounted for 8% of the total hydraulic load, 44% of the BOD and 59% of the salt generated in the manufacture of process pack products.

There are several sources of wastes from tank yard operations. These include spillage, tank overflow during rainy periods, leakage from wooden tanks, spent fermentation brine and "process water" generated during desalting operations. This project was designed to evaluate recycling of spent brines as a means for control of this source of waste.

Usual fermentation practices will result in production of about 40% by volume spent brine in a fermentation tank. The cucumber fermentation is normally done at 6.5% NaCl (3). However, when the fermentation is completed, additional salt is added to insure against deterioration of the fruit during tank yard storage. As a result, spent brines usually contain 9-15% NaCl, the BOD will be 10,000-15,000 mg/l and the pH will be 3.2-3.5. These characteristics make biological treatment of waste relatively difficult. Discharge of brines produced by tank yard operations may not be possible in some locations with limits on total dissolved solids.

In assessing environmental control strategies available for managing these brines one may wonder if it is feasible to either reclaim the salt contained therein, or to recycle the spent solution.

Durkee et al. (4) has developed a procedure for salt recovery from fermentation brines by evaporation of the water and incineration of the organic matter. Salt recovered by this method has been used successfully in cucumber fermentations (5). However, this technique has not been adopted commercially due to the high cost of equipment and energy.

When considering brine recycling, many concerns arise. One is the potential for loss of product quality if pectinases were carried over in the recycled brine at levels sufficient to soften cucumbers during months of fermentation and storage in the brine. It is also possible that products of fermentation could inhibit subsequent fermentations or cause abnormal fermentations. There could also be a buildup of toxic compounds. The destruction of these products might require incineration or other drastic techniques. Pathogenic organisms will not, however, be a problem due to the low pH and high salt content of the brine.

Geisman and Henne (6, 7) developed a chemical treatment procedure for reclaiming spent fermentation brines. Their procedure requires raising the pH of spent brine to 10 or 11. This treatment clarified the brine, since a precipitate formed which occluded suspended cells. It was also presumed to inactivate pectinase activity. After a 48-hr holding period, the pH was adjusted to 7 and the brine used as a cover brine for fermentation. Normal fermentations resulted from use of this brine. This showed that incineration was not required for reuse of salt and provided a practical alternative treatment.

Palnitkar and McFeeters (8) showed that chemically treated brine could be used for multiple fermentation cycles without loss of salt stock quality. They also suggested that heating of brine could be used as an alternative treatment and suggested 175°F for 30 sec. as a reasonable heat treatment.

Cranfield (9) had previously reported on a system for pasteurization of brine, saturation of the treated brine by addition of salt and reuse of the treated brine as a saturated salt solution.

The primary objectives of this project were to evaluate the commercial, technological, and economic feasibility of brine recycling by both heat and chemical treatments and to determine the relative merits of these two procedures.

The recycling procedures were compared to controls in which cucumbers were fermented in fresh salt brine. The control fermentations were done according to normal commercial brining procedures. The commercial fermentations were carried out at the Imlay City, Michigan plant of Vlasic Foods, Inc.

SECTION 2

CONCLUSIONS

1. Brine recycling is an effective procedure for reduction of waste in the manufacture of salt-stock pickles.
2. Both the heat and chemical treatments for spent brine are practical for use in current commercial tank yard operations.
3. Heating spent brine for 30 sec. at 175°F will assure at least 99.98% destruction of pectinases from fungi which were found to be common on cucumber fruits and flowers.
4. Raising the pH of $\geq 72^\circ\text{F}$ spent brine to 11.2 or higher for at least 37 hr will decrease Penicillium janthinellum pectinase activity in spent brines to $< 1\%$ of its initial activity. This should be an adequate treatment for brine recycling.
5. Salt-stock cucumbers produced from fermentations using recycled brines are equivalent to control salt stock in bloater losses, texture, and flavor. Consumers have not detected any significant differences in products prepared from salt stock fermented in recycled brine.
6. No significant accumulations of metals or pesticides occur as a result of brine recycling.
7. The results show that brine can be reused for at least three fermentation cycles on a commercial basis. There are also no indications of adverse effects of recycling on salt-stock quality or buildup of toxic constituents. This suggests that brine can continue to be reused beyond three cycles.
8. Under the conditions of this project, heat treatment of brine resulted in a small net savings while there was a small net cost for chemical treatment. The relative economics of these two recycling procedures may vary with individual circumstances. However, the use of recycling is an economically feasible means for reducing the waste from tank yard operations.

SECTION 3

RECOMMENDATIONS

1. Brine recycling should be adopted by the processed cucumber pickling industry as a means to reduce wastes.
2. Both heat and chemical treatments of the spent brine are effective from a technical viewpoint. Selection of a procedure can be based upon economic considerations and upon the relative compatability of the procedures with each particular tank yard operation.
3. Care should be taken to insure proper design of a recycling system, proper training of operating personnel and proper supervision of the procedure, since improper recycling techniques hold the potential for significant economic losses.
4. Undertake an evaluation of calcium hydroxide as a partial or total replacement of sodium hydroxide in the chemical treatment procedure. The use of calcium hydroxide would significantly reduce the accident risks associated with this procedure.
5. Evaluate the need to remove the precipitate formed during chemical treatment. If precipitate removal is unnecessary, it would reduce brine losses and reduce handling of the brine.
6. Efforts should be made to reduce tank leakage and overflow, since significant brine losses occur from these sources.
7. A major effort is needed to develop salt-stock storage technology, which will allow reduction in the salt levels maintained in brining tanks, since wastes generated in the desalting operation are second only to spent brine as a source of waste in tank yard operations.

SECTION 4

EXPERIMENTAL DESIGN

BRINE TREATMENT PROCEDURES

Chemical Treatment of Brine

Chemical treatment of spent brine was carried out by the addition of Food Grade NaOH pellets to a tank of spent brine (8,000-10,000 gal) to raise the pH of the brine to 11 or greater.

The amount of NaOH required for each batch of brine was determined by titrating a 32-oz, spent brine sample from a well mixed tank with 10% NaOH solution to a pH of 11.5. Approximately 80% of the calculated NaOH requirement was added to the tank and the brine was circulated. A sample of this partially adjusted brine was titrated to pH 11.5, and the NaOH requirement calculated. This amount of NaOH was added and the tank was circulated with a pump. A characteristic change in color of the spent brine to darker yellow, development of an ammonia-like odor and formation of a precipitate occurred as the pH was raised. This two-step NaOH addition procedure provides insurance against major errors in the amount of NaOH added and attainment of the proper final pH.

A precipitate formed when the brine pH was raised. This precipitate settled in the tank. After settling, the clear brine was pumped into a clean tank. The precipitate layer was discarded. The pH of the NaOH treated brine was adjusted to pH 4.5-4.7 with 300 grain vinegar. The amount of vinegar required was determined by titration of a sample with acetic acid. Addition was done by the same procedure as the addition of NaOH. After acidification of the brine, it was held until it was used as a cover brine.

Great care must be exercised when using sodium hydroxide for pH adjustments. Injuries were prevented by use of the following precautions:

1. Only college students who had taken introductory chemistry handled the sodium hydroxide.

2. These people were specifically taught the problems and dangers associated with handling NaOH.
3. Protective clothing including wrap around goggles, acid-base resistant gloves, and rain suit was required for handling NaOH.
4. A water hose was turned on when NaOH was being handled so any spills could be rapidly washed. Eye wash equipment was readily available.
5. NaOH was slowly added by manual addition while the brine tank was mixing to minimize the possibility of local high concentrations of NaOH on the surface of the tank.

Heat Treatment of Spent Brine

Spent brine was heated with a trailer mounted brine recovery system developed by the APV Company, Inc. of Tonawanda, New York and Vlastic Foods. A schematic diagram of the unit is shown in figure 1. Figure 2 shows a drawing of the heat exchanger system. The unit has a titanium alloy heat exchanger to resist brine corrosion, a 200 gal stainless steel holding tank, and a screening system to remove particulate materials from the brine before it enters the heat exchanger.

The heat exchanger heats brine from ambient temperature to 68°C (155°F) by regeneration from the heated brine. Heating from 68°C up to 90.5°C (195°F) is done with hot water heated by burning propane. This system allows up to 60% of the heating to be obtained by cooling the treated brine to a temperature of 35°C (95°F).

The entire unit is mounted on a 6 x 16 ft trailer so it can be moved between tank rows. In routine operation it was most efficient to pump brine from nearby rows of tanks to minimize the number of times the unit had to be moved. The unit can be loaded on a truck and transported to other tank yard locations. In this way one unit has been used to serve more than one location. The unit has required relatively little maintenance and does not appear to be deteriorating significantly even though several million gallons of brine have been treated.

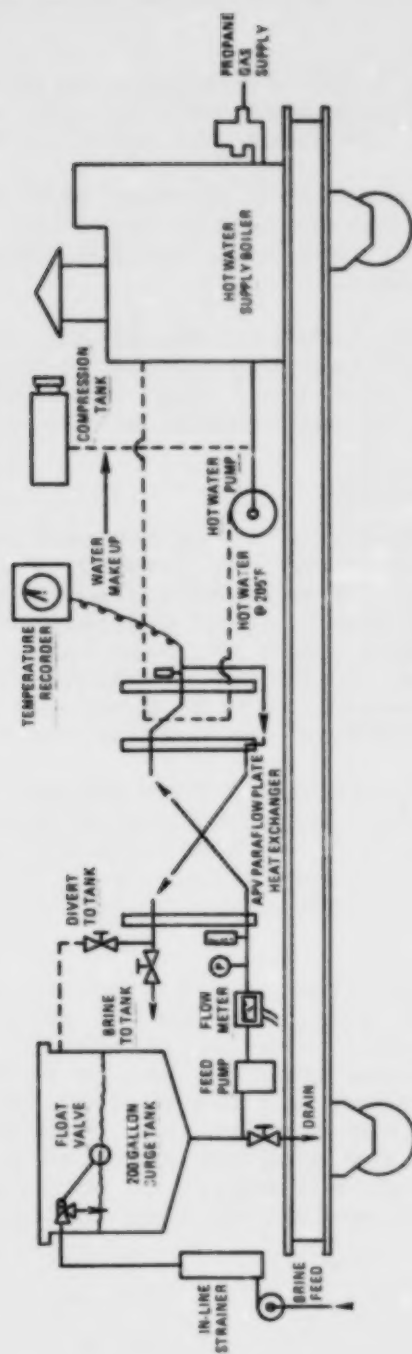
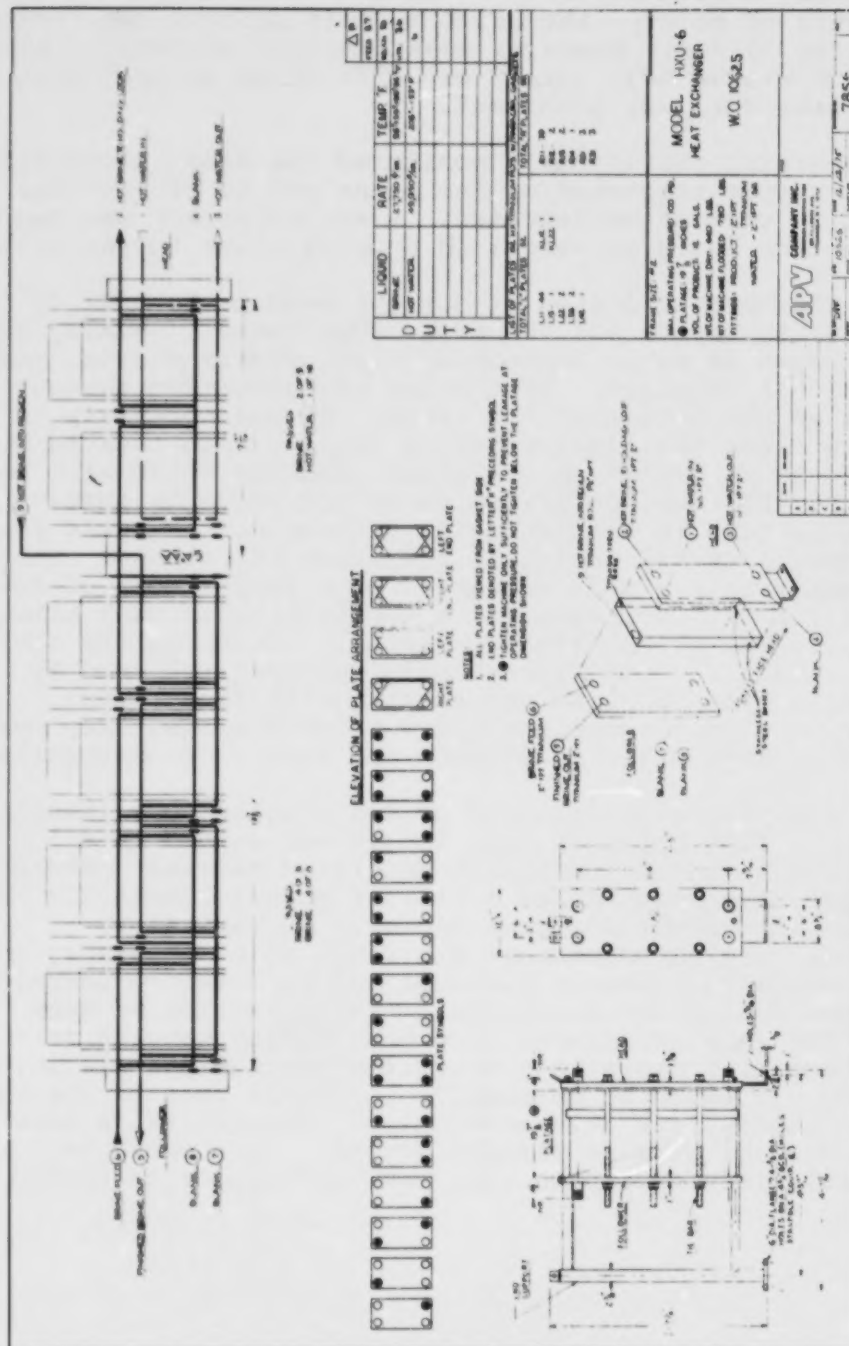


Figure 1. Schematic diagram of the brine recovery unit.



Bottled propane gas was used as the fuel source. The heat exchanger had a heat capacity of 50 gal/min. To provide an extra margin of safety, the brine in this project was treated to 190°F for 30 sec. Whenever feasible, the heating of brine was done on warmer days (>21°C or 70°F) since warmer brine required less fuel for treatment.

An operator continuously monitored the heating operation to assure proper treatment of the brine and to protect the equipment in case of malfunction. A second person was required on a part-time basis to assist in pumping brine to the unit.

The flat-bottom design of current wood tanks made it impractical to remove all the brine from tanks. Usually about a 6 inch layer of brine containing dirt, pickle debris, and other residues remained. This brine was discarded through the bung hole in the bottom of the tanks. It was necessary to thoroughly clean the tanks prior to filling with treated brine. Though the tanks cannot be sterilized and the brine will be open to the air, the contamination of the brine by pumping into a dirty tank is aesthetically unpleasing and could result in considerable yeast growth in the brine before use. The brine comes from the heat exchanger at a temperature of 90-100°F. Therefore, it will not sanitize a poorly cleaned tank prior to cooling. Tanks were cleaned by manually scrubbing the tanks with 0.5 oz/gal calcium hypochlorite solution followed by washing with hydrated lime and rinsing with fresh water. If tanks were not used immediately for brine storage, they were filled with fresh water to prevent the wood from contracting.

The treated brine was held at its original pH, usually at pH 3.2-3.5. Just prior to use, the pH was raised to 4.5 with NaOH pellets using the procedure described earlier. Etchells et al. (10) have recommended a similar pH adjustment for fresh brine used in controlled fermentation. In laboratory experiments this pH adjustment was found to be necessary in order to minimize bloating problems and to obtain a normal acid development during fermentations. The quantities of NaOH required for this adjustment have been safely handled in normal commercial operations using the precautions previously described. It would be worthwhile to obtain data on the use of lime, Ca(OH)_2 , for this adjustment. Calcium salts have been added to pickles as firming agents. Lime would be considerably less expensive than NaOH and easier to handle.

Controls for Fermentations With Recycled Brine

Commercial practice for cucumber fermentations has historically been to cover the fresh cucumbers with freshly prepared brine. At the conclusion of fermentation and storage, the brine remaining after salt stock was removed from tanks was termed "spent brine" and discarded. To evaluate the effects of brine recycling it was necessary to compare the salt stock and brines from fermentations with recycled brines with fermentations in which green stock cucumbers were covered with freshly prepared salt solutions.

COMMERCIAL EVALUATION OF BRINE RECYCLING

Fermentation brines were reclaimed and reused through three complete fermentation cycles per treatment as shown in figure 3. The project began in 1975 with the segregation of first cycle spent brine from the general tank yard brines. After heating or chemical treatment, it was used for second cycle fermentations in 1975. The second cycle brine was saved and treated in the spring of 1976 for third cycle fermentations. Control fermentations in which cucumbers were covered with fresh salt brine were run in both 1975 and 1976.

Size 3A-3B (3.8-5.1 cm diam) mixed cucumbers were used for all tanks. These sizes of cucumbers are fermented in greatest volume commercially. In addition, the large size cucumbers are most susceptible to bloating. One objective of the project was to determine if brine recycling would significantly affect bloating. Tank sizes varied from 800-1,200 bu capacity. For the control fermentations, freshly prepared, 6.6% NaCl cover brine was used. Recycled brine was added to cucumbers without dilution. The salt concentrations varied from 10-12% NaCl. The salt concentration declined as the brine equilibrated with the water in the cucumbers. In all tanks dry salt was added to the tanks as required to maintain the salt concentration of 6.6% (25° S) during the fermentation. At the end of the fermentation period, salt was added according to the usual schedule to slowly raise the salt to 11%.

Tanks were filled in groups of three consisting of a control tank, a tank in which heated brine was used and a tank into which chemically treated brine was added. During the 1975 season, nine complete groups of tanks were fermented to give nine replicates per treatment. During the 1976 season, eight groups of tanks were fermented. In this instance, the number of groups was limited by the amount of the second cycle chemically treated brine available.

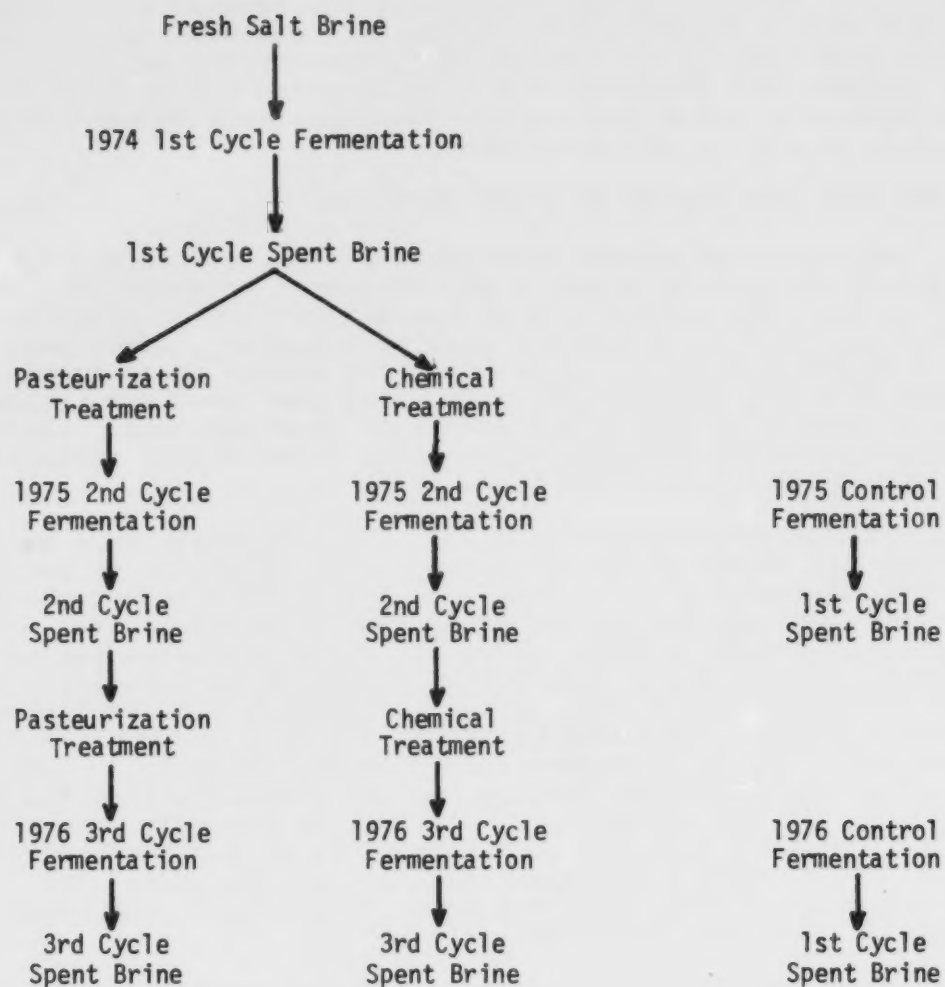


Figure 3. General design of the commercial evaluation of brine recycling.

When groups of tanks were filled, 1,000-lb tote boxes of cucumbers were dumped alternately into the tanks to assure similar cucumbers were put in each tank. Fresh cucumber samples were evaluated for mechanical damage, carpel separation, loose seed cavities, and other defects.

Recycled brine was sampled in the spring before and after treatment prior to use in the fermentations. These samples were used for salt, pH, acid, reducing sugar, suspended solids, BOD, COD, Kjeldahl nitrogen and mineral analyses. Addition of salt was recorded throughout the fermentation. Brine from each tank was sampled for the same analyses listed above in the winter when cucumbers were removed for processing. Two 5-gal pails of cucumbers were taken from each tank for analysis of nitrogen and mineral components. One pail of cucumbers was desalted in the laboratory with tap water. A 10 kg sample of salt stock and desalted cucumbers was diced with a vegetable dicer and homogenized without addition of water with a Bronwill Polytron homogenizer. A 1 liter sample of each homogenate was kept for analysis.

The brine and cucumber samples were refrigerated when they were collected in the tank yard. The samples were frozen in the laboratory. For mineral and Kjeldahl nitrogen analyses, the samples were held from 1-6 months prior to analyses. Brine samples for determination of BOD, COD, suspended solids, titratable acidity, and NaCl were refrigerated. The BOD was run within 3 days of receipt of the samples. The other analyses were completed within 1 week.

To evaluate the commercial quality of salt stock produced with recycled brine, samples of 200 cucumbers were taken from each tank. They were classified into three categories by tank yard personnel. Good cucumbers were those with no internal defects. Commercially acceptable cucumbers included the good cucumbers plus those with slight bloater or honeycomb defects which could be sliced into dill chips with only small losses. Commercially unacceptable stock had severe bloater or honeycomb defects which made it suitable only for less valuable relish stock. The texture of desalted cucumbers was evaluated by a puncture test with a 5/16 inch diameter probe. This was similar to the test developed by Bell and Etchells (11) using a Magnus-Taylor manual pressure tester. The test was done with an Instron Universal testing instrument (Instron Corp., Canton, MA). The force required to puncture the cucumber was determined by running a 5/16 inch diameter probe vertically into the fruit at a speed of 50 cm/min. The recorder was set to record 20 kg pressure full scale. Twenty cucumbers from each tank were punctured. The average peak force required to puncture the cucumbers was calculated.

A taste panel evaluation of the final product made from 2nd and 3rd cycle stock and the corresponding control stock was conducted. Hamburger dill chips from the 2nd and 3rd cycles were prepared by desalting the stock and using commercial procedures of Vlasic Foods, Inc.

The difference test score sheet (Figure 4) was used for the taste test evaluation (12) ("Reference Guidebook for Sensory Testing," 3rd edition, 1966, Continental Can Co., Inc., Chicago, IL). The score sheet is divided into three parts. In the first part the control sample is evaluated for flavor, texture and overall quality in an "excellent" to "poor" rating. In the second part the judges compare the heat and chemical treatments with the control on the scale of 0 (no difference) to 5 (very large difference). Part III compares overall quality of the treatments with the control product on the scale of 1 (much worse) to 4 (same) to 7 (much better). The data were analyzed using analysis of variance procedures.

During the fermentation of the cucumbers, the brines were analyzed for salt, pH and titratable acidity. These were the normal analyses performed in commercial operations. Salt was measured using a hydrometer to determine the percent saturation of a salt solution. In addition, salt was measured by titrating brine samples with 0.171 N AgNO_3 . The results were expressed as degrees salometer. A 1% change in salt concentration is approximately equivalent to a change of 4° salometer. The pH was measured with a glass electrode. Titratable acidity was determined by titration of a brine sample with NaOH to phenolphthalein end point or pH 8. Results were expressed as percent lactic acid.

Bloater damage was evaluated on each commercial tank of cucumbers according to the criteria used in standard commercial operations at Vlasic. The tanks were emptied from October to March. The salt stock was desalted to approximately 4% NaCl according to the commercial practice of Vlasic Foods, Inc. and processed into final products, primarily hamburger dill chips.

Brine was analyzed for BOD (13), COD (14), and suspended solids (15) using standard methods. Reducing sugar was determined with the dinitrosalicylic acid reagent (16). Nitrogen was measured using a microKjeldahl procedure (17).

Brine and cucumber samples were assayed for lead, cadmium and chromium by atomic absorption spectrophotometry. A method described by Sprague and Slavin (18) and by Thomas et al. (19) was used with quantities of samples appropriate for cucumbers and brine. A 40 ml aliquot of brine or a 40 g sample of ground cucumbers was added to a 250 ml Erlenmeyer flask together with 35 ml of concentrated nitric acid. The sample was boiled

DIFFERENCE TEST

Name: _____

Date: _____

I. Sample K is the standard, or reference sample. Please rate K below:

Overall Quality of K (circle one)	Comments	
	Flavor	Texture
Excellent	Excellent	Excellent
Good	Good	Good
Fair	Fair	Fair
Poor	Poor	Poor

II. Please compare the samples to K for texture and flavor differences. Test samples may or may not be different from the reference sample. Rate each sample according to this difference scale:

<u>Rating</u>	<u>Difference from Standard</u>
0	No difference
1	Very slight difference
2	Slight difference
3	Moderate difference
4	Large difference
5	Very large difference

Test Sample No.	Difference Ratings		Comments	
	Texture	Flavor	Texture	Flavor

III. Quality of samples compared to K:

	<u>Test Sample #</u>	<u>Test Sample #</u>
Much worse	_____	_____
Moderately worse	_____	_____
Slightly worse	_____	_____
Same	_____	_____
Slightly better	_____	_____
Moderately better	_____	_____
Much better	_____	_____

Figure 4. Score sheet for taste panel evaluation of hamburger dill chips.

gently on a hotplate for approximately 3 hr until it turned clear and had reached a volume of 10 ml. The sample was then cooled to room temperature and the pH adjusted to 3.0 with ammonium hydroxide. After cooling again to room temperature, 5.0 ml of 2% ammonium pyrrolidine dithiocarbamate was added. The flask was swirled and then allowed to stand for 10 min. Then 10 or 20 ml of methyl isobutyl ketone (MIBK) was added. The solution was shaken for 2 min and allowed to stand until it became clear. The MIBK phase was then removed and analyzed.

Mercury analysis was based on the method developed by Hatch and Ott (20). In determining mercury levels, 40 ml of brine or 40 g of ground cucumber was transferred to a 250 ml Erlenmeyer flask and dried on a hotplate at 71°C for approximately 20 hr or until the sample appeared moisture free. The sample was cooled to -18°C, then 20 ml concentrated nitric acid was added and the sample was allowed to stand for 1 hr at room temperature. After heating on a steam bath for 4 hr, 15 ml of concentrated sulfuric acid was added and heating was continued until the brown nitrous fumes were driven off (approximately 1 1/2 hr). The sample was cooled on ice and 15 ml of KMnO_4 (5% w/v) was added. The sample was heated on a steam bath for 30 min to complete the sample preparation. When the solution was cooled to room temperature, the mercury concentration was measured with a Coleman model MAS-50 mercury analyzer.

Phosphorus, calcium, magnesium, manganese, iron, copper, boron, zinc, and aluminum levels were determined by atomic emission spectroscopy (21). Brine or ground cucumber samples were dried in porcelain crucibles on a hotplate at <100°C over a 32-hr period. The dried samples were ashed in a muffle furnace at 400°C for 7 hr. Samples were analyzed by the Michigan State University Leaf Analysis Laboratory.

SPECIAL STUDIES

Certain studies were done separate from commercial brine recycling to evaluate potential difficulties with recycling. These included an evaluation of pesticide buildup with multiple reuse of brine, determination of the temperature and pH stability of fungal pectinases which are most likely to occur in fermentation brines and a measurement of lysinoalanine in chemically treated brine.

Effect of Brine Recycling on the Buildup of Pesticide Residues

Selected cucumber plots were treated with twice the recommended dosage of pesticides at half of the recommended intervals before harvest. The plants were treated with Terrachlor Super X (pentachloroaniline), Demesan (chloroneb), parathion, Thiodan (endosulfan), and Sevin (carbaryl). Demesan was not applied in 1977 because it was dropped from consideration for use on cucumbers.

The cucumbers were shipped to Michigan State University and brined without sizing or washing. Approximately 110 lb of cucumbers were placed in each of seven tanks and covered with brine to give a pack-out ratio of 57:43 by weight of cucumbers to brine. For the first cycle all seven tanks of fresh cucumbers were covered with fresh 6.6% NaCl solution. In subsequent cycles the control tank was covered with fresh brine, three tanks were covered with heat treated brine from the previous cycle, and three tanks were covered with chemically treated brine.

The fermentations were carried out indoors under ultraviolet lights to retard the growth of film yeasts. Dry food-grade salt was added to the tanks as required to maintain the salt concentration at 6.6%.

At the end of the fermentation, usually 3-4 weeks, the cucumbers were removed from the tanks, the brines were treated and used as a cover brine on the next batch of fresh cucumbers.

Samples were taken for pesticide analysis of fresh washed and unwashed cucumbers, brined cucumbers, and brine before and after heat or chemical treatment. The cucumbers for the washed sample were sprayed with tap water from a spray nozzle for 2 min. The water flow rate was 10 kg/min. For fresh and brined cucumber samples, 10 kg of cucumbers were diced on a vegetable slicer and then homogenized with a Bronwill Polytron tissue grinder.

Brines and cucumbers were analyzed by extraction of pesticide materials followed by gas-liquid chromatography. Solvents used in the analysis were methylene chloride, acetone, ethyl acetate, and petroleum ether (boiling range 30-60°C). These solvents were obtained commercially, distilled in glass, from Burdick and Jackson Laboratories, Inc., Muskegon, Michigan 49422. Chloroneb, PCNB, pentachloroaniline (PCA), parathion, paraoxon, Bravo®, Dathal®, Difolatan®, endosulfan I, endosulfan II, endosulfan sulfate, and carbaryl were obtained from Pesticide Reference Standards Section, Chemistry Branch, Registration Division, room 5175, South Agriculture Building, Environmental Protection Agency, Washington, DC 20460.

Bio Beads S-X3-200-400 mesh, control no. 13127, catalog no. 154-2750, were purchased from Bio-Rad Laboratories, Richmond, California 94804.

Two gas chromatographs were used for the analysis. The instruments, columns and operating conditions were as follows:

- (1) Perkin Elmer model 910 equipped with nitrogen-phosphorus detector (NPD).

Columns - 1.8 m x 4 mm id glass columns packed with 10% OV-101 and 10% OV-101 + 15% OV-210 (1 + 1), both on Chromosorb W-HP, 80-100 mesh, conditioned 48 hr at 250 °C with ca. 20 ml/min N₂ flow.

Operating conditions - temperatures (°C) - column 210, injector 230, detector 250; nitrogen carrier gas, 60 ml/min; NPD bead temperature - 10 turn pot setting 630 or to give approximately 50% full scale deflection (FSD) for 8 ng carbaryl on 1 mv recorder, but not to exceed a dull red glow of detector bead. Detector gas flows - hydrogen 3 ml/min, air 38 ml/min. Nitrogen and phosphorus containing compounds can both be determined under the above conditions, however, the response for phosphorus is extremely high. To circumvent making large dilutions, the phosphorus compounds were quantitated with a flame photometric detector.

- (2) Tracor model MT 222 equipped with linearized ⁶³Ni electron capture detector (ECD) and flame photometric detector (FPD) connected in parallel with column effluent splitter.

Column - 1.8 m x 4 mm id glass column packed with 10% OV-101 on Chromosorb W-HP, 80-100 mesh conditioned for 48 hr at 250°C with ca. 20 ml/min N₂ flow.

Operating conditions - temperature (°C) - column 200, injector 230, detectors 350 (ECD), 220 (FPD). Argon carrier gas - 60 ml/min, split at column exit with 1 part to ECD and 19 parts to FPD. Purge gas to ECD - 70 ml/min argon-methane (95 + 5). ECD attenuation set to give 40-60% FSD for 1 ng injected heptachlor epoxide with signal fed to 1 mv recorder. FPD operating conditions - hydrogen 50 ml/min, air 80 ml/min, electrometer settings so that 2 ng of injected parathion gives 40-60% FSD into a 1 mv recorder.

Gel permeation chromatography was performed with a GPC Autoprep 1001 (Analytical Bio Chemistry Laboratories, Inc., Columbia, Missouri 65201) equipped with a 2.5 x 50 cm column packed with Bio Beads S-X3. Methylene chloride at a 5 ml/min flow rate was used as the solvent. Usual practice was to discard the effluent for 29 min and then to collect the sample for 24 min. However, dump and collection times may vary depending upon flow rate, column packing, etc. Each column and instrument should be calibrated with the compounds of interest before analysis of samples is begun.

Samples were concentrated with a 500 ml Kuderna-Danish concentrator fitted with a three-ball Snyder column (Kontes Glass Co., K-570000 or equivalent). The lower joint of the concentrator must fit a 19/22 of a 10 ml Mills-type graduated tube (Kontes Glass Co., K-570050 or equivalent).

Samples were blended with a Sorvall blender equipped with a 500 ml, stainless steel cup (Ivan Sorvall, Inc., Newton, CT 06470 or equivalent).

Brine solutions were shaken before sampling to obtain an even distribution of any settled material. Raw and brined cucumbers were chopped in a food chopper to give a homogenous mass. Samples were extracted according to the procedure of Luke et al. (22). Brine (40 g) was weighed into a 125 ml, glass stoppered Erlenmeyer flask, 80 ml of acetone was added, and the sample was thoroughly mixed. For raw or brined cucumbers a 100 g chopped sample was added to the blender cup, 200 ml acetone was added and the sample was blended at high speed for 2 min. The slurry was centrifuged and the supernatant decanted through a glass wool plug into a 300 ml glass stoppered Erlenmeyer flask. Alternately, the sample could be filtered with suction through a 12 cm Buchner funnel fitted with sharkskin filter paper.

Eighty ml of extracts, whether from brine or cucumbers, was transferred to a 1 liter separatory funnel. One hundred ml each of petroleum ether and methylene chloride were added. The funnel was shaken vigorously for 1 min, the layers were allowed to separate and the lower aqueous phase was drained into a 250 ml separatory funnel containing 7 g NaCl. This funnel was shaken for 30 sec to dissolve most of the NaCl. The upper phase from the 1 liter separatory funnel was passed through a 5 cm column of anhydrous granular Na_2SO_4 into a 500 ml Kuderna-Danish concentrator fitted with a 10 ml graduated tube. The 1 liter separatory funnel was rinsed with 100 ml methylene chloride. This solvent was then added to the 250 ml separatory funnel to re-extract the aqueous phase. The funnel was shaken for 1 min and the lower methylene chloride phase was drained through the Na_2SO_4 column into the Kuderna-Danish concentrator.

The aqueous phase was extracted with another 100 ml portion of methylene chloride. After extraction, this solution was also dried and added to the concentrator. The combined methylene chloride extracts were evaporated to about 2 ml with the aid of a three-ball Snyder column. It was necessary to take care to prevent solvent from boiling into the column at the beginning of the evaporation.

The concentrated extract was diluted to 7.0 ml with methylene chloride in the graduated tube. The sample (5.0 ml) was loaded into the sample loop of the Autoprep 1001 and chromatographed by dumping 29 min (145 ml) and collecting for 24 min (120 ml). "Cleaned up" extract was collected and concentrated in the Kuderna-Danish concentrator to approximately 2 ml. The tube containing sample was removed from the concentrator. The sample was evaporated to dryness with a slight current of air or nitrogen and minimal heat. The dried sample was dissolved in 3.0 ml ethyl acetate for initial injection on the gas chromatograph equipped with the NPD for quantitation of carbaryl. Appropriate dilutions were made for injection on the ECD/FPD equipped chromatograph.

Sample represented in the final ethyl acetate extracts was calculated as follows:

Cucumbers: $100 \text{ g} / (200 \text{ ml} + 94 \text{ ml} - 10 \text{ ml}) \times 5 \text{ ml} / 7 \text{ ml}$;
where 94 ml was the volume of water present in the cucumbers, 10 ml was the water-acetone contraction factor and 5 ml/7 ml was the quantity of sample used for GPC cleanup.

Brine: $40 \text{ g} / 80 \text{ ml} + 34 \text{ ml} - 2.5 \text{ ml} \times 5 \text{ ml} / 7 \text{ ml}$;
where 34 ml was the volume of water in the brine sample containing 15% solids and 2.5 ml was the water-acetone contraction factor.

Pectinase Inactivation

The possibility for introduction of pectinases into spent brines, either from the previous fermentation or during periods of brine storage, was a major concern in the development of recycling procedures. If these enzymes were not properly controlled, serious softening of cucumber salt stock could result.

Etchells et al. (23) did a survey of the fungi present on cucumber fruits and flowers. They identified the most common molds and found that all of the species investigated produced pectinase activity. It was their opinion that enzymes from the dominant molds would be the usual cause of commercial cucumber softening.

Pectinase was produced by growing each of the organisms studied on the following medium (24): NH_4NO_3 (1 g/l), MgSO_4 (0.3 g/l), yeast extract (Difco) (0.1 g/l), KH_2PO_4 (0.01 M) and citrus pectin (Sigma) (5.0 g/l). The pH was adjusted to 6.4 with 4 N NaOH prior to sterilization of the medium. Fernbach flasks containing 1 liter of media were inoculated with appropriate organisms and shaken at 110 rpm on a rotary shaker. Cultures were grown at room temperature (21-24°C) until enzyme activity reached its maximum level.

Fungal cells were removed from the medium by centrifugation for 5 min at 12,000 x g. The supernatant was filtered through a 0.45 μ pore diameter Millipore filter. The cell free filtrate, containing pectinase activity, was concentrated with an Amicon model 402 ultrafiltration cell using a UM-10 membrane with a molecular weight cutoff of approximately 10,000 daltons.

For thermal inactivation studies pectinase concentrates were added to brine solutions such that during inactivation 12% NaCl, 0.6% lactic acid and 0.1% Ca^{++} ion were present in the brine. The brine pH was adjusted to 3.3 to 4.7 depending upon the particular experiment. Brines were heated for specific time intervals in 4.5 mm I.D. test tubes sealed with paraffin and cooled in an ice bath. The enzyme activity remaining was measured by the rate of viscosity change in a 1.0% pectin solution in pH 4.0, .015 M lactate buffer. The time required for 90% inactivation of enzyme activity (D-value) was determined from the linear portion of a plot of the logarithm of the percent activity remaining as a function of time.

Inactivation of pectinase at high pH was done in simulated spent brines in which Ca^{++} ion was omitted to avoid formation of a precipitate. Glycine (0.02 M) was added to provide buffer capacity at high pH in the brine. It was necessary to flush with nitrogen gas and tightly close test tubes with corks or rubber stoppers to prevent the brine pH from dropping during incubation. The pH drop was apparently a result of CO_2 absorption during incubation.

The pH of the high pH brines was adjusted to 4.0 with 1 N HCl prior to measuring the remaining enzyme activity. Activity was determined as described above. The inactivation of pectinases at high pH did not follow first order reaction kinetics. As a result, D-values could not be determined.

Enzyme containing brines for inactivation experiments in commercial spent brines were prepared by dialyzing enzyme concentrate in a large excess of spent brine. This was done to prevent dilution of brine constituents by the enzyme solution.

Lysinoalanine Content of Chemically Treated Brine

Formation of lysinoalanine by base treatment of protein had been reported by DeGroot and Slump (26). Woodward and Short (27) had reported that free lysinoalanine was toxic to rats. Though cucumber brines are low in protein, the high pH required for chemical treatment provided the potential for formation of this compound.

To determine whether significant amounts of lysinoalanine could be formed by chemical treatment a first cycle, commercial spent sample brine was used. The brine was adjusted to pH 11.4 and held at room temperature (23°C) for 8 days. The clear supernatant brine was removed and the pH adjusted to 4.6 with glacial acetic acid. Samples of untreated and base treated brine were dialyzed against water to remove salt and low molecular weight components. The dialyzed samples were concentrated on a flash evaporator with the water bath heated to 40°C. Aliquots of the concentrates were hydrolyzed at 100°C with 6 N HCl. The hydrolysate was chromatographed on a Beckman, 120C amino acid analyzer using the column for basic amino acid. Authentic lysinoalanine was chromatographed to verify the position on the chromatogram and for quantitative standardization of the column.

SECTION 5

RESULTS AND DISCUSSION

CHARACTERISTICS OF RECYCLED BRINES

Brine samples were collected before and after heat and chemical treatment for the first cycle brines in 1975 and for second cycle brines in 1976. Tables 1 and 2 show the mean values for the results of the analysis done on these brine samples. The data were analyzed by an analysis of variance procedure to determine the changes which occur as a result of heat or chemical treatment.

There were no significant differences between the untreated brines used for the first cycle heat treatment and chemical treatment in 1975. This was expected since these brines were randomly selected from the tank yard and assigned to either the heat or chemical treatment. A more limited analysis of brine samples was done previously (8). The levels observed in this project for the mineral components of the brines were similar to those obtained in the earlier study.

Heat treatment caused few changes in the brine. The pH and titratable acidity were increased and decreased, respectively. NaOH was added after heat treatment to effect those changes. There was approximately a doubling of the aluminum level.

Chemical treatment caused a number of changes in the brines. The pH and titratable acidity changed as expected. Reducing sugars declined under the alkaline conditions. Formation and removal of a precipitate reduced the suspended solids. BOD and COD increased as a result of vinegar addition for pH adjustment. Several of the mineral components of brine, including P, Ca, Mg and Fe, declined as a result of chemical treatment. It was found previously (8) that the precipitate formed consisted primarily of mineral material. Aluminum was the only mineral component to show an increase.

TABLE 1. CHARACTERISTICS OF 1ST CYCLE SPENT BRINE IN THE SPRING OF 1975 BEFORE AND AFTER HEAT OR CHEMICAL TREATMENT. THE TREATED BRINES WERE USED AS COVER BRINES FOR 2ND CYCLE FERMENTATIONS

Parameter	Heat treatment		Chemical treatment	
	Untreated	Treated	Untreated	Treated
Acid % lactic	0.45 B*	0.17 A	0.47 B	0.23 A
Salt %	13.1	12.5	13.2	12.7
pH	3.58 A	4.63 B	3.53 A	4.80 B
Sugar mg/l	405 B	272 AB	392 B	190 A
Suspended solids mg/l	254 B	204 B	231 B	55 A
BOD mg/l	10300 b	9700 b	10600 b	14000 a
COD mg/l	14200 b	12800 b	14000 b	17200 a
Kjeldahl N mg/l	594	507	564	523
Cd mg/l	.015	.038	.093	.058
Hg mg/l	0	0	0	0
P mg/l	130 B	111 B	116 B	26 A
Ca mg/l	1010 B	978 B	1020 B	714 A
Mg mg/l	141 B	130 B	130 B	12 A
Mn mg/l	2.7	2.5	3.4	1.9
Fe mg/l	6.2 B	6.7 B	7.2 B	2.5 A
Cu mg/l	1.6	1.6	2.0	1.3
B mg/l	1.4	1.3	1.4	1.2
Zn mg/l	4.9	4.3	5.0	3.2
Al mg/l	5.3 a	10.7 b	6.1 a	11.6 b
Cr mg/l	.003	.003	.003	.001

*Samples with different letters are significantly different. With upper case letters, differences are significant at the 1% level. With lower case letters, differences are significant at the 5% level.

TABLE 2. CHARACTERISTICS OF 2ND CYCLE SPENT BRINE IN THE SPRING OF 1976 BEFORE AND AFTER HEAT OR CHEMICAL TREATMENT. THE TREATED BRINES WERE USED AS COVER BRINES FOR 3RD CYCLE FERMENTATIONS

Parameter	Heat treatment		Chemical treatment	
	Untreated	Treated	Untreated	Treated
Acid % lactic	0.62 B*	0.21 A	0.63 B	0.26 A
Salt %	11.4	11.8	11.0	10.8
pH	3.52 C	4.55 A	3.66 B	4.95 A
Sugar mg/l	263 B	222 B	258 B	115 A
Suspended solids mg/l	298	206	158	87
BOD mg/l	12500 b	14000 ab	14500 ab	17400 a
COD mg/l	18600 b	19300 b	19500 b	22700 a
Kjeldahl N mg/l	583	621	601	507
Cd mg/l	0.013	0.012	0.012	0.015
Hg mg/l	0.003	0.003	0.003	0.003
P mg/l	139 A	128 AB	100 B	11.0 C
Ca mg/l	1042 A	1123 A	960 A	652 B
Mg mg/l	173 A	183 A	140 B	5 C
Mn mg/l	1.4	1.7	1.0	0.6
Fe mg/l	9.3	11.2	17.5	4.9
Cu mg/l	1.4	1.6	1.0	1.6
B mg/l	1.4	1.6	1.3	1.5
Zn mg/l	4.8	5.6	4.2	3.6
Al mg/l	8.3 A	12.3 A	7.1 A	31.2 B

*Samples with different letters are significantly different. With upper case letters, differences are significant at the 1% level. With lower case letters, differences are significant at the 5% level.

In 1976 the second cycle spent brines were treated prior to the third cycle fermentations. Prior to treatment, a few differences were observed between the brines which had been heat treated and chemically treated the previous year. The pH of the chemical treatment brine was 3.66 compared to 3.52 for the heat treatment brine. This difference was significant at the 1% level. It is thought to be the result of vinegar addition which caused an increase in buffer capacity in the chemical treatment brine. Phosphorus and magnesium were also reduced in the chemical treatment brines.

Heat treatment of the second cycle brine resulted in no significant change in brine composition except for the increase in pH and decrease in titratable acidity. Chemical treatment caused significant changes in the same components and in the same directions in 1976 and 1975 with the exception of BOD and Fe. In those two instances there were differences in the same directions as were observed in 1975. However, the differences were not significant at the 5% level.

Comparison of the heat treated first and second cycle brines showed an increase in BOD from 9700 mg/l to 14,000 mg/l and COD from 12,800 mg/l to 19,300 mg/l. In addition, there were small increases in the concentration of P, Ca and Mg. For chemical treatment this first and second cycle comparison showed that BOD and COD increased. Though the levels of P, Ca and Mg were lower in treated brines, the levels in 1975 were actually slightly higher than in 1976. This may have been a result of more efficient removal of precipitate in 1976.

The results of these experiments showed that heat treatment had no effect upon the brine constituents, except for aluminum and the pH and titratable acidity, which were intentionally altered. Chemical treatment results in a decline of many, but not all, of the mineral constituents of brine. The BOD and COD are increased as a result of vinegar addition. Aluminum levels increased after completion of brine treatment with both the chemical and heat techniques. It may be that the food grade NaOH, which was used in both procedures, contains some aluminum as an impurity.

Third cycle brines were removed from cucumber fermentation tanks after the third cycle fermentations. The composition of the third cycle brines is given in Tables 5 and 6. The concentrations of mineral constituents were similar to the concentrations before treatment of the first and second cycle brines. Since the project was concluded at the end of the third cycle of fermentation, the third cycle brines were not treated.

CHARACTERISTICS OF CUCUMBERS AND FERMENTATIONS

Tables 3 and 4 summarize the numbers of tanks operated in this project and the amount of cucumbers and brines used. The control tanks were covered with 6.6% (25° S) NaCl brine at the beginning of cucumber fermentation. This was the usual commercial practice for using fresh brines. Recycled brines were used at whatever salt concentration was present after brine treatment. This averaged about 12.5% in 1975 and 11% in 1976. The ability to use a high salt cover brine is a necessary part of successful recycling, since dilution of brine to 6.6% would require discharge of a large fraction of spent brine due to the excess volume generated.

The cover brine was diluted as it equilibrated with the water in the cucumbers. To maintain the salt concentration at 6.6% during fermentation, dry salt was added to the tank headboards. These tanks were fermented as nonpurged, natural fermentations. This was the usual fermentation procedure at the time this project was initiated. Recently Costilow et al. (28) reported on a nitrogen-purging procedure which was designed to remove CO₂ from natural fermentations. The technique was shown to significantly reduce bloaters during cucumber fermentations. The prospect is that a significant proportion of commercial fermentations will be using this technique in the immediate future. Vlasic has used the purging technique in combination with recycled brine without difficulty in fermentation tanks which were not part of this project. No variations in brine composition would be anticipated as a result of using purging, since the only effect of the technique is to circulate the brine during the fermentation period in such a way that CO₂ generated by the microorganisms and the fruit can be efficiently removed.

TABLE 3. SUMMARY DATA ON FERMENTATION TANKS, 1975

	Control	Heat treatment	Chemical treatment
Number of tanks	10	11	10
Bushels of cucumbers	7660	8668	7388
Gallons of brine	34321	31418	30881
Gallons of brine/bushel	4.48	3.62	4.18
Pack-out ratio	57:43	62:38	59:41

TABLE 4. SUMMARY DATA ON FERMENTATION TANKS, 1976

	Control	Heat treatment	Chemical treatment
Number of tanks	8	8	8
Bushels of cucumbers	5727	5604	5727
Gallons of brine	19832	20780	19960
Gallons of brine/bushel	3.46	3.71	3.49
Pack-out ratio	63:37	62:38	63:37

Tables 5 and 6 show the composition of spent brines at the time cucumbers were removed from the fermentation tanks. The control brines in 1975 and 1976 were first cycle spent brines. The tanks which contained heat and chemically treated brines were second cycle fermentations in 1975 and third cycle fermentations in 1976. When second cycle brines were compared to the 1975 first cycle control brines, the only significant differences were a higher final pH in the recycled brine tanks and a higher aluminum level in the heat treated brine than in the control. The heat and chemical treated brines differed from each other in suspended solids, but neither was significantly different from the control.

Comparison of third cycle brines with the 1976 first cycle control brines showed an increase in pH, reducing sugar, BOD and COD in the chemically treated brines. The heat treated brines differed from the control only in pH, BOD and COD. The heat treatment brines had a higher Ca and Mg content than the chemical treatment. However, the control tanks showed intermediate levels which were not significantly different from either the heat or chemical treatment brines.

The rise in final pH in recycled brine tanks was expected because the buffer capacity of the recycled brines would retard the drop in pH during fermentation. BOD and COD levels in brines were also expected to increase because of the carry-over of organic matter when brines were recycled. None of the changes affected the course of fermentation to any practical degree. Observations of the progress of fermentations and the tank yard operations with recycled brine showed that recycling can be done without changing the tank yard operation during the fermentation period.

TABLE 5. ANALYSIS OF SPENT BRINE REMAINING IN THE FERMENTATION TANKS IN THE WINTER AFTER REMOVAL OF SALT STOCK CUCUMBERS FROM THE 2ND CYCLE (1975) AND 3RD CYCLE (1976) FERMENTATION TANKS

	Control	Heat treatment	Chemical treatment
<u>2nd cycle, 1975 data</u>			
Acid % lactic	0.67	0.68	0.73
Salt %	9.6	10.1	9.4
pH	3.36 A*	3.48 B	3.57 B
Sugar mg/l	367	415	325
BOD mg/l	14700	14300	16300
COD mg/l	17600	19200	20500
Suspended solids mg/l	342 ab	553 b	265 a
<u>3rd cycle, 1976 data</u>			
Acid % lactic	0.57	0.74	0.77
Salt %	8.6	9.7	8.7
pH	3.55 a	3.65 b	3.65 b
Sugar mg/l	186 A	176 A	259 B
BOD mg/l	12500 A	19200 B	19600 B
COD mg/l	17000 A	23900 b	23100 b
Suspended solids mg/l	552	379	612

*Samples with different letters are significantly different. With upper case letters, differences are significant at the 1% level. With lower case letters, differences are significant at the 5% level.

TABLE 6. ANALYSIS OF SPENT BRINE REMAINING IN THE FERMENTATION TANKS IN THE WINTER AFTER REMOVAL OF SALT STOCK CUCUMBERS FROM THE 2ND CYCLE (1975) AND 3RD CYCLE (1976) FERMENTATION TANKS. ALL DATA ARE EXPRESSED AS mg/l OF BRINE*

Element	Control		Heat treatment		Chemical treatment	
	1st cycle 1975	1st cycle 1976	2nd cycle 1975	3rd cycle 1976	2nd cycle 1975	3rd cycle 1976
N	582	543	656	755	665	692
Cd	.008	.012	.006	.020	.005	.019
Hg	0	.008	0	.010	.001	.005
P	128	252	134	322	127	165
Ca	1130	958 ab	1180	1391 a	1120	774 b
Mg	137	213 ab	142	261 a	120	146 b
Mn	3.0	1.3	3.1	2.0	2.3	1.4
Fe	8.9	11.9	10.0	17.9	11.0	9.8
Cu	2.9	0.4	1.8	1.1	1.3	1.3
B	1.3	1.4	1.4	1.8	1.3	1.3
Zn	4.3	2.8	4.7	4.7	3.9	2.8
Al	7.3 b	12.1	12.6 a	22.3	9.9 ab	25.1
Pb	0	0	0	0	0	0
Cr	0	-	0	-	0	-

*Treatments were compared within the same year by analysis of variance. Samples with different letters are significantly different. With lower case letters, differences are significant at the 5% level. With upper case letters, differences are significant at the 1% level.

Salt stock quality was evaluated for cucumbers fermented in recycled brines. Bloating has traditionally been a major source of defects in fermented fruit. Bloating results in significant economic loss because seriously bloated fruit can only be utilized in lower price relish products. Tables 7 and 8 show the results of bloater evaluations on second and third cycle salt stock. In both 1975 and 1976, the control was first cycle salt stock. No significant differences were found between fruit fermented in recycled brines and the controls. This showed that bloater defects will neither increase nor decrease as a consequence of recycling. As stated above, if fermentations were properly purged, significant decreases in bloater defects could be obtained.

TABLE 7. QUALITY OF 2ND CYCLE SALT STOCK CUCUMBERS
FERMENTED IN RECYCLED BRINE, 1975*

	Control	Heat treatment	Chemical treatment
Good stock (%)	72.8	72.8	73.0
Commercially acceptable (%)	85.3	86.5	86.5
Commercially unacceptable (%)	14.7	13.5	13.5

*No significant differences among treatments.

TABLE 8. QUALITY OF 3RD CYCLE SALT STOCK CUCUMBERS
FERMENTED IN RECYCLED BRINE, 1976*

	Control	Heat treatment	Chemical treatment
Good stock (%)	52.1	46.0	54.0
Commercially acceptable (%)	84.9	80.2	82.6
Commercially unacceptable (%)	15.1	19.9	17.4

*No significant differences among treatments.

In addition to bloater defects, the salt stock was routinely evaluated for overall commercial acceptability at the time of processing. Cucumbers fermented in recycled brine were judged to have normal texture, color and odor. Instron pressure test evaluation of the desalted stock from second cycle fermentations showed no significant differences in the stock from recycled brines. The average pressure test was 17.5 lb for the control, 18.4 lb for the stock from heat treated brine and 18.3 lb for stock from chemically treated brine. On the scale proposed by Bell et al. (11), the fruit would be rated very firm.

Taste panel evaluations were done on hamburger dill chips prepared from control salt stock and from salt stock from second and third cycle fermentations. Tables 9 and 10 show the average scores for second and third cycle products and corresponding control samples. The last column shows the cumulative averages. The control samples were rated fair to good when evaluated for flavor, texture and overall quality.

Tables 11-15 show the results of analysis of variance of the differences in texture, flavor and overall quality of products prepared from control and recycled fermentations. There were no significant differences between the control and product prepared from salt stock fermented in either heat treated or chemically treated, recycled brine.

Based upon commercial experience, there does not appear to be any significant deterioration or improvement in the quality of products obtained from fermentation in recycled brine. There have been no complaints from either institutional or individual consumers of these products which have been related to use of recycled brine.

TABLE 9. COMPARISON OF 2ND CYCLE PRODUCT WITH THE CONTROL (AVERAGES), 3
SAMPLES/GROUP, 9 JUDGES AND 7 GROUPS

	1	2	3	4	5	6	7	Cumulative average
<u>I. Evaluation of control</u>								
Overall quality	2.89	2.22	2.44	1.89	3.00	2.11	2.89	2.49
Texture	3.56	3.11	2.89	3.22	3.67	2.00	3.00	3.06
Flavor	2.89	2.33	2.55	2.11	3.00	2.22	2.78	2.56
<u>II. Texture differences</u>								
Heat treatment	1.56	1.78	1.33	1.55	1.11	2.00	1.22	1.51
Chemical treatment	2.78	1.44	1.11	2.67	0.78	2.78	1.33	1.84
<u>III. Flavor differences</u>								
Heat treatment	1.44	1.78	3.67	3.00	1.56	1.67	3.22	2.33
Chemical treatment	4.11	1.67	3.33	2.67	2.11	2.11	2.22	2.62

TABLE 10. COMPARISON OF 3RD CYCLE PRODUCT WITH THE CONTROL (AVERAGES),
3 SAMPLES/GROUP, 11 JUDGES AND 5 GROUPS

3 SAMPLES/GROUP, 11 JUDGES AND 5 GROUPS

	Groups					Cumulative average
	1	2	3	4	5	
<u>I. Evaluation of control</u>						
Overall quality	2.54	2.73	3.0	2.73	2.45	2.69
Texture	3.36	3.09	3.0	2.64	2.09	2.84
Flavor	2.36	2.36	2.73	3.0	2.55	2.60
<u>II. Texture differences</u>						
Heat treatment	1.54	1.36	1.09	2.63	2.72	1.87
Chemical treatment	1.18	2.45	1.45	2.72	3.45	2.25
<u>III. Flavor differences</u>						
Heat treatment	2.36	2.27	1.82	2.0	1.45	1.98
Chemical treatment	3.64	3.18	2.10	3.64	1.73	2.84
<u>IV. Overall quality differences</u>						
Heat treatment	4.18	4.45	3.73	4.82	4.09	4.25
Chemical treatment	3.64	3.64	4.09	3.45	4.0	3.76

TABLE 11. ANALYSIS OF VARIANCE TABLE FOR TEXTURE
DIFFERENCES OF HAMBURGER DILL CHIPS MADE
FROM 2ND CYCLE SALT STOCK CUCUMBERS*

Source	df	ss	MS	F
Treatments	1	3.50	3.50	1.64
Groups	6	33.16	5.53	2.60
Treatments x groups	6	12.78	2.13	
Judges	8	23.59	2.95	1.00
Judges x treatments	8	2.86	0.36	0.12
Judges x groups	48	141.91	2.96	
Judges x groups x treatments	48	59.86	1.25	

*No significant differences

TABLE 12. ANALYSIS OF VARIANCE TABLE FOR FLAVOR
DIFFERENCES OF HAMBURGER DILL CHIPS MADE
FROM 2ND CYCLE SALT STOCK CUCUMBERS*

Source	df	ss	MS	F
Treatments	1	2.57	2.57	0.41
Groups	6	46.65	7.78	1.24
Treatments x groups	6	37.76	6.29	
Judges	8	12.29	1.54	0.70
Judges x treatments	8	7.43	0.93	0.42
Judges x groups	48	105.49	2.20	
Judges x groups x treatments	48	40.24	0.84	

*No significant differences.

TABLE 13. ANALYSIS OF VARIANCE TABLE FOR TEXTURE
DIFFERENCES OF HAMBURGER DILL CHIPS
MADE FROM 3RD CYCLE SALT STOCK CUCUMBERS

Source	df	ss	MS	F
Treatments	1	4.0	4.0	2.30
Groups	4	56.68	14.17	8.14*
Treatment x groups	4	6.96	1.74	
Judges	10	26.05	2.61	0.82
Judges x treatments	10	12.10	1.21	0.38
Judges x groups	40	127.32	3.18	
Judges x groups x treatments	40	59.54	1.49	

*Significantly different at $p = .05$.

TABLE 14. ANALYSIS OF VARIANCE TABLE FOR FLAVOR
DIFFERENCES OF HAMBURGER DILL CHIPS
MADE FROM 3RD CYCLE SALT STOCK CUCUMBERS*

Source	df	ss	MS	F
Treatments	1	20.08	20.08	9.21
Groups	4	33.81	8.45	3.88
Treatments x groups	4	8.70	2.18	
Judges	10	16.29	1.63	0.74
Judges x treatments	10	15.02	1.50	0.68
Judges x groups	40	87.99	2.20	
Judges x groups x treatments	40	36.70		

*No significant differences.

TABLE 15. ANALYSIS OF VARIANCE TABLE FOR OVERALL
QUALITY DIFFERENCES OF HAMBURGER DILL
CHIPS MADE FROM 3RD CYCLE SALT STOCK
CUCUMBERS*

Source	df	ss	MS	F
Treatments	1	6.64	6.64	2.74
Groups	4	0.86	0.22	0.09
Treatments x groups	4	9.68	2.42	
Judges	10	22.70	2.27	0.72
Judges x treatments	10	13.26	1.33	0.42
Judges x groups	40	126.94	3.17	
Judges x groups x treatments	40	64.92	1.62	

*No significant differences.

The concentrations of several minerals in the salt stock and the desalted cucumbers were analyzed to determine the degree of buildup of these materials which might result from recycling brine. Results of these analyses are summarized in Tables 16 and 17. The second cycle salt stock showed no significant differences in the mineral content compared to the control first cycle salt stock except that at the 5% significance level, the level of Al in the heat treatment salt stock was higher than for the control or chemically treated samples. The third cycle samples from heat treated brine had higher levels of Mg, Mn and Fe than the control. There were no significant differences between the samples from chemically treated brine and the control samples.

After desalting the salt stock cucumbers in the second cycle samples, the only significant difference was a higher Mn level in the samples from heat treated brine and a lower Al level in samples from chemically treated brine compared to heat treated brine samples. The third cycle samples showed no differences between the control and either recycled brine technique. The only difference significant at the 5% level was a higher Mg concentration in samples from heat treated brines compared to samples from chemically treated brines. In several instances there were lower levels of minerals in the desalted cucumbers in 1975 compared to 1976 in all three groups of samples. This was attributed to the fact that in 1975 the cucumbers were desalted to <1% NaCl. In 1976 desalting was done to bring the salt concentration down to 4%. This was closer to actual commercial practice.

The results of the mineral analysis did not show any buildup of elements to illegal or potentially toxic levels in the spent brines (Table 6), the salt stock (Table 16) or the desalted cucumbers (Table 17). The Pb was below detectable levels. The lowest detectable level was estimated to be approximately 0.05 ppm. Samples were analyzed for chromium in 1975. Most samples contained no detectable chromium. As a result, this analysis was not done in 1976.

The data on the commercial quality of salt stock, on the composition of spent brines before and after treatment, on the course of fermentation and on the mineral components of cucumbers before and after desalting led to the following conclusions regarding the technological aspects of brine recycling.

1. Major changes in tank yard practice were not required for brine recycling.
2. Fermentations proceeded normally. The same criteria used to judge completion of fresh brine fermentations could be used to judge fermentations with recycled brine.

TABLE 16. SALT STOCK CUCUMBER ANALYSIS. DISTRIBUTION OF MINERAL LEVELS IN COMMERCIAL SALT STOCK DURING THREE CYCLES OF FERMENTATION. ALL DATA ARE EXPRESSED AS mg/kg OF CUCUMBERS*

Element	Control		Heat treatment		Chemical treatment	
	1st cycle 1975	1st cycle 1976	2nd cycle 1975	3rd cycle 1976	2nd cycle 1975	3rd cycle 1976
N	592	746	466	796	726	814
Cd	.057	.014	.032	.015	.061	.021
Hg	.006	.004	.009	.003	.019	.006
P	130	248 ab	145	321 a	136	168 b
Ca	924	954 ab	920	1308 a	992	810 b
Mg	134	198 b	136	275 a	113	141 b
Mn	1.7	1.5 B	1.8	2.5 A	2.4	1.2 B
Fe	9.5	13.5 b	13.0	22.3 a	11.0	11.1 b
Cu	1.1	1.6	1.3	1.7	1.6	1.1
B	1.4	1.7	1.5	2.1	1.6	1.6
Zn	3.3	3.0	3.4	3.9	4.1	3.4
Al	7.2 b	14.7	11.5 a	22.8	8.4 b	11.7
Pb	0	0	0	0	0	0
Cr	.010	-	.012	-	.017	-

*Treatments were compared within the same year by analysis of variance. Samples with different letters are significantly different. With lower case letters, differences are significant at the 5% level. With upper case letters, differences are significant at the 1% level.

TABLE 17. DESALTED CUCUMBER ANALYSIS. DISTRIBUTION OF MINERAL LEVELS IN DESALTED CUCUMBERS DURING THREE CYCLES OF FERMENTATION. ALL DATA ARE EXPRESSED AS mg/kg OF CUCUMBERS*

Element	Control		Heat treatment		Chemical treatment	
	1st cycle 1975	1st cycle 1976	2nd cycle 1975	3rd cycle 1976	2nd cycle 1975	3rd cycle 1976
N	399	589	364	678	348	626
Cd	.039	.013	.081	.009	.064	.017
Hg	.015	.004	.019	.004	.009	.006
P	56	210	58	216	53	260
Ca	372	671	327	912	331	564
Mg	59	156 ab	56	186 a	53	102 b
Mn	0.06 b	0.9	0.29 a	0.8	0.06 b	1.0
Fe	6.1	18.8	7.8	16.1	6.0	11.6
Cu	0.7	1.2	0.7	1.2	0.6	1.6
B	0.6	1.3	0.6	1.5	0.6	1.3
Zn	0.3	1.6	1.2	1.7	0.2	1.7
Al	7.0 ab	23.7	7.1 a	17.9	4.9 b	12.9
Pb	0	0	0	0	0	0
Cr	.016	-	.012	-	.018	-

*Treatments were compared within the same year by analysis of variance. Samples with different letters are significantly different. With lower case letters, differences are significant at the 5% level. With upper case letters, differences are significant at the 1% level.

3. Treated brine which contained 12.5% NaCl could be used without dilution as a cover brine. This yielded salt stock equivalent in quality to control tanks.
4. Changes in brine or cucumber composition as a result of recycling were small. There were no significant buildups of toxic elements in brines or cucumbers which would indicate that recycling should not be done or that the number of brining cycles would need to be limited.
5. From a technical point of view, recycling the brine was practical and resulted in final products which were commercially equivalent to the controls.

ECONOMIC ANALYSIS OF BRINE RECYCLING

The economics of brine recycling must be analyzed for each particular case. The costs and savings realized for this project are summarized in Tables 18, 19 and 20. Table 18 shows the savings to be realized as a result of recycling brine. Salt which was reused represented a direct savings. The calculation was done on the basis of 12% salt in spent brine. The savings in treatment costs can be quite variable. In this project waste was treated in an on-site, aerated lagoon. A cost of 8¢/lb BOD treated was estimated. No dollar cost could be placed upon the fact that less salt was discharged as a result of recycling. However, the plant had a stringent limit upon its discharge of salt. Reduction of NaCl levels in the effluent was essential to continued operation of the plant. A small cost saving was realized as a result of reuse of water.

The costs of the chemical treatment procedure are shown in Table 19. The labor cost was difficult to evaluate because of the small scale of the chemical treatment operation. Since the time required was intermittent rather than continuous, as was the case with the heat treatment procedure, the labor cost was estimated to be 50% of the labor cost for pasteurization. The major costs were NaOH and vinegar. In 1975 an average of 44 lb NaOH/1,000 gal of treated brine was required. In 1976 this increased to 52 lb. The vinegar use, calculated on the basis of equivalent glacial acetic acid, also increased from 30 lb/1,000 gal in 1975 to 36 lb/1,000 gal in 1976. These increases may reflect an increase in buffer capacity of the second cycle spent brine compared to first cycle brine. The high cost of chemicals resulted in a small net cost for chemical treatment. No capital investment was required for the project. However, if chemical treatment were used as the sole brine treatment procedure in a tank yard, the quantities required might make it necessary to purchase storage tanks for the NaOH and acetic acid along with metering equipment.

TABLE 18. SAVINGS FROM RECYCLING 1,000 GAL OF SPENT BRINE

Item	Dollars saved
NaCl, 1.08 lb/gal @ \$20/ton	10.76
BOD, 12,000 mg/l at 8¢/lb	8.00
Water, 47¢/1,000 gal	.45
Total savings	19.21

TABLE 19. ECONOMIC EVALUATION OF CHEMICAL TREATMENT OF SPENT BRINES

Item	1975 Cost (\$/1,000 gal)	1976 Cost (\$/1,000 gal)
Labor @ \$4/hr	0.84	1.32
NaOH, 1975 19.5¢/lb 1976 17¢/lb	8.58	8.84
Vinegar, 1975 \$1.01/gal 1976 94¢/gal	11.87	13.32
Total cost	21.29	23.48
Total savings	19.21	19.21
Net cost	2.08	4.27

TABLE 20. OPERATING COSTS AND SAVINGS USING HEAT
TREATMENT FOR SPENT BRINES

Item	1975 Cost (\$/1,000 gal)	1976 Cost (\$/1,000 gal)
Labor @ \$4/hr	1.67	2.64
Propane	1.23	1.29
Pumping	0.71	0.71
NaOH, 1975 19.5¢/lb 1976 17¢/lb	2.76	2.41
Total operating costs	6.37	7.05
Total savings	19.21	19.21
Net savings based upon operating costs	12.84	12.16

The operating costs for heat treatment were considerably lower than for chemical treatment. A major cost was the purchase of a \$44,575 APV titanium alloy regenerative heat exchanger with a brine treatment capacity of 50 gal/min. This first heat exchanger has been used for three brining seasons without showing signs of major deterioration. In 1976 the cost of a new 50 gal/min capacity heat exchanger unit, with some improvements and revisions of the first model, was approximately \$60,000. The present cost of a basic turn-key unit with a capacity of 50 gal/min with minimum instrumentation and convenience features is \$50,000. A similar unit with a 35 gal/min capacity costs approximately \$40,000.

An estimate of whether it is worth purchasing a heat exchanger unit, considering the difference in operating costs between chemical and heat treatment of brine, was made by doing a calculation of the net present value (29) of the difference in operating costs between chemical and heat treatments. Such an estimate is highly dependent upon the assumptions used for the calculation. Each company considering brine recycling must make the decision between treatments based upon their particular circumstances.

The results of the net present value calculation are shown in Table 21. The following assumptions were used in making the calculation.

1. A heat exchanger unit with a treatment capacity of 35 gal/min will be purchased for \$40,000.
2. The heat exchanger unit will be utilized at full capacity 14 hr/day, 20 days/month for 3 months to treat 1.7 million gal of brine.
3. The interest rate will be 8.5%.
4. The difference between the operating costs of chemical and heat treatments will remain constant.
5. The maintenance cost of the brine recycling heat exchanger will be \$500/yr.
6. The useful life of the heat exchanger unit will be 5 yr.
7. The value of the unit will be zero after 5 yr.
8. The capital cost of the chemical treatment will be zero.

TABLE 21. NET PRESENT VALUE CALCULATION FOR COMPARISON OF CHEMICAL TREATMENT WITH HEAT TREATMENT OF BRINE. THE DIFFERENCE BETWEEN TREATMENT COSTS PER 1,000 GAL FOR CHEMICAL COMPARED TO HEAT TREATMENT OF BRINE WAS \$16.43 IN 1976. FOR 1.7 MILLION GAL THIS IS A TOTAL DIFFERENCE IN TREATMENT COST OF $1700 \times \$16.55 = \$27,931$. WITH A MAINTENANCE COST OF \$500/YR FOR THE UNIT THE NET DIFFERENCE IS \$27,431.

Years of use of the heat exchanger unit	Present value of \$27,431 at 8.5% interest
1	25,282
2	23,301
3	21,476
4	19,794
5	18,243
Total present value of difference in costs between chemical and heat treatments	<u>108,096</u>
Present value of heat exchanger unit	40,000
Net present value	<u>68,096</u>

Based upon these assumptions, the present value of the savings to be realized over a 5-yr period by using heat treatment is over \$108,000. Since the cost of the heat exchanger will be about \$40,000, resulting in a net present value of over \$68,000, the heat treatment procedure would be the treatment of choice. This calculation was repeated making the same assumptions as before except that only 50% as much brine was treated. In that case there was still a positive net present value of over \$13,000 when heat treatment was used.

In summary, it appears that either chemical or heat treatment can be utilized without making the cost of brine recycling prohibitive. It appears that in many situations, the heat treatment procedure would be economically advantageous. However, an analysis must be made for each particular situation considering local economic and physical conditions.

POTENTIAL FOR REDUCTION OF WASTE

Table 22 shows the raw waste loads for fresh pack, process pack and pickle salting stations as published by EPA (30). On April 16, 1976 the EPA published in the Federal Register (31) a notice of effluent guidelines for existing sources and pretreatment standards for new and existing sources covering the canned and preserved fruit and vegetable point source category. Table 23 shows the effluent guidelines which must be met as of July 1, 1977 using "best practical control technology currently available" (BPCTCA). The "best available technology economically achievable" (BATEA) must be in place by July 1, 1983 to meet the effluent limitations shown in Table 24.

EPA has not developed limitations on total dissolved solids (salt). However, many states have placed limits on salt discharge. Therefore, in the design of waste reduction systems, processors must consider reductions in salt as well as BOD, TSS and flow rates.

The problem of spent brine discharge from a tank yard must be considered both in terms of direct BOD and TSS discharge and its detrimental effects upon the waste treatment system. If the spent brine is to be accommodated in an existing waste treatment facility, it can cause several problems. The increased salt levels will reduce oxygen solubility, thus lowering treatment efficiency, and the intermittent nature of this high BOD, high salt wastewater will cause a shock effect to most biological treatment systems. The ultimate result will be higher costs for the treatment operation.

TABLE 22. RAW WASTE LOAD SUMMARY*

Item	Flow gal/ton		BOD lb/ton		TSS lb/ton	
	1977	1983	1977	1983	1977	1983
Fresh pack	2051	1878	19.0	5.89	3.82	1.91
Process pack	2298	1481	36.7	17.2	6.54	1.57
Salting stations	253	77	15.9	3.17	0.83	0.43

*EPA 440/1-75/046, p. 197. Development Document for Interim Final and Proposed Effluent Limitations Guidelines and New Source Performance Standard.

TABLE 23. EPA EFFLUENT GUIDELINES - 1977*

Item	Raw (lb/1,000 lb)		
	Daily maximum	30 Day average	Annual average
<u>Fresh pack</u>			
BOD	1.22	0.75	0.53
TSS	2.19	1.54	0.99
<u>Process pack</u>			
BOD	1.45	0.92	0.68
TSS	2.63	1.91	1.28
<u>Salt stations</u>			
BOD	0.18	0.12	0.09
TSS	0.33	0.25	0.18

*Best Practical Control Technology Currently Available (BPCTCA). Effective 7/1/77.

TABLE 24. EPA EFFLUENT GUIDELINES - 1983*

Item	lb/1,000 lb		
	Daily maximum	30 Day average	Annual average
<u>Fresh pack</u>			
BOD medium [†]	0.639	0.461	0.213
large [‡]	0.639	0.461	0.213
TSS medium	1.139	0.606	0.429
large	0.639	0.461	0.213
<u>Processed pack</u>			
BOD medium	0.652	0.511	0.313
large	0.652	0.511	0.313
TSS medium	1.208	0.784	0.643
large	0.652	0.511	0.313
<u>Salt stations</u>			
BOD medium	0.084	0.072	0.054
large	0.084	0.072	0.054
TSS medium	0.163	0.125	0.113
large	0.084	0.072	0.054

*Best Available Technology Economically Achievable (BATEA). Effective 7/1/83.

[†]Medium - 2,000 to 10,000 tons/yr.

[‡]Large - 10,000 tons or more/yr.

Table 25 shows the theoretical salt use based upon the recommendations of Etchells and Moore (3) for the fermentation of cucumbers. The amount of salt added after fermentation is completed varies from company to company. In most instances the final level is 11% (45° S) NaCl or higher. The table shows the amount of salt used at several final salt concentrations. If brine recycling is not used, the salt discharge will be that shown in the final column of the table. If fermentation brines could be 100% recycled, the salt in the spent brine would be recovered and reused.

The salt removed in the process water must still be discharged with current technology. Reduction of this source of waste can be accomplished only by developing new fermentation procedures which will allow storage at lower salt concentrations and/or developing new economical procedures for concentrating and reusing the dilute process water.

The heat treatment procedure should result in recycling approximately 95% of the spent brine with its organic and inorganic waste load. Removal of the precipitate layer formed by chemical treatment will limit brine recovery to approximately 90%. It must be pointed out that the brine recovery accomplished in this project was achieved with tanks which were not designed to recover the brine. Improvement in this aspect of recycling is certainly feasible if future tanks are designed to maximize brine recovery. For example, a conical tank bottom would minimize the volume of brine containing excessive dirt and debris and increase the percentage of brine in a tank which could be readily pumped out.

A salt balance study was done to determine the quantity of salt which is lost from tank leakage and runover. This study showed a loss of 0.25 to 1.0 lb of salt per bu of cucumbers. The losses from leaky tanks can be partially controlled by careful maintenance of the tanks. However, development of economical liners for wooden tanks or conversion to fiberglass or other tank materials will probably be necessary for effective control of this effluent. Tank overflow during rainy periods can only be stopped if fermentation technology is developed which allows tanks to be covered during fermentation and storage. The controlled fermentation process developed by Etchells et al. (10) offers this possibility.

TABLE 25. THEORETICAL SALT USE AND DISCHARGE DURING FERMENTATION, STORAGE, UNTANKING AND DESALTING OF CUCUMBERS. RESULTS ARE EXPRESSED AS THE LB OF SALT REQUIRED PER BU (50 LB) OF FRESH CUCUMBERS

Stage of processing	Final salt concentration °S							
	25	30	35	40	45	50	55	60
1. 25° S cover brine	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84
2. Dry salt added to maintain 25° S during fermentation	3.46	3.46	3.46	3.46	3.46	3.46	3.46	3.46
3. Raising salt concentration from 25° S to final level	0	1.12	2.26	3.42	4.60	5.80	7.00	8.27
4. Total salt utilized, sum of 1-3	5.30	6.42	7.56	8.72	9.90	11.10	12.30	13.57
5. Spent brine (3.8 gal/bu)	2.19	2.65	3.12	3.60	4.09	4.58	5.10	5.60
6. Cucumbers upon removal from tanks	3.11	3.77	4.44	5.12	5.81	6.52	7.20	7.97
7. Cucumbers after desalting, 4% final salt concentration in fruit	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21
8. Process water	0.90	1.56	2.23	2.69	3.60	4.31	4.99	5.76
9. Total losses without brine recycling sum of 5 and 8	3.09	4.21	5.35	6.51	7.69	8.89	10.09	11.36

It appears that brine recycling is an economically attractive operation for inclusion into process packers' environmental control systems. However, effluent problems can not be solved simply by introduction of brine recycling into the tank yard operation. Kirk (2) reported that spent brine accounted for 8% of the total hydraulic load, 44% of the BOD and 59% of the salt generated in a pickle salting station. Even if complete recycling of spent brine were achieved, it would be necessary to greatly reduce tank leakage, tank overflow, spillage and most importantly, desalting water (process water) in order to meet the 1983 limitations. Therefore, a continuing development of new technology must occur if the pickling industry is to remain viable. Effective application of brine recycling technology will be one step in this process.

RESULTS OF SPECIAL STUDIES

Pesticide Distribution in Brine Recycling

The study was performed to evaluate conditions representing the extreme misuse of pesticides. The cucumbers were raised on a selected plot of land and were treated at twice the recommended dosage with pesticides normally used by cucumber growers. In addition, the cucumbers were harvested at half the post-harvest interval recommended by the Environmental Protection Agency.

Methodology to determine the selected compounds simultaneously could not be found. However, the procedure of Luke et al. (22) extracts many more pesticides than are included in this study and is rapid and easy to perform. The decision was made to expand this extraction into a suitable method for the selected compounds. Since the extract was too dirty for direct quantitation using ECD and since several of the compounds are not recovered through the PAM Florisil cleanup (35), gel permeation chromatography was investigated.

Initially a 2.5 x 25 cm column packed with Bio Beads S-X3 and methylene chloride mobile solvent was tried. The separation between the sample extractives and the pesticides was borderline at best and the decision was made to try a 50 cm column. Separation was improved although some of the extractives had to be collected to insure good recoveries of parathion and paraoxon. These extractives did not interfere with the GLC quantitation by ECD.

The effect of direct evaporation of the GPC eluant of methylene chloride from the collection beakers was compared to evaporation using a Kuderna-Danish concentrator (Table 26). The recovery of pesticides from cucumbers, brines and with no sample substrate is also shown in Table 26. The unusually low recoveries of Bravo® and Difolatan® in the Kuderna-Danish evaporation compared to the higher recoveries through the proposed method could not be explained. The final evaporation to dryness is critical. The methylene chloride must be removed; however, if the tube is allowed to remain under the air or nitrogen jet after dryness, loss of residues can occur, especially chloroneb, PCNB, PCA and Bravo®.

The cucumbers for pesticide distribution studies were harvested, analyzed for residues and brined in seven 55-gal drums. At the end of each brining cycle, a portion of the brining solution was removed from each of the seven drums and saved for analysis as untreated brine. The remainder of the brines in drums 1, 3 and 4 were screened to remove large debris and pasteurized at 175°C for 25 sec in a heat exchanger. After treatment, the brines were pumped back into their respective drums and the pH of the brine was adjusted with NaOH just prior to reuse.

The remainder of the brines in drums 5-7 were treated with NaOH to raise the pH to 11.0 and allowed to stand for 48 hr. The pH was then adjusted with acetic acid and the large debris was screened out just prior to reuse.

The treated brine in each drum was then reused with another batch of pesticide treated cucumbers. This process was repeated for each cycle. Three cycles were performed in 1975 and an additional three cycles were completed in 1976. The same brining solutions were used throughout the six cycles.

The brine in drum no. 2 was carried through the six cycles as a "control" and was neither pasteurized nor chemically treated except to readjust the salt content or the pH.

The effects of the pasteurization and chemical treatments on the residues in the brining solutions can be seen in Tables 28-31. Chloroneb®, Bravo®, Dacthal®, Difolatan®, and paraoxon showed no more than trace residues in any of the samples run through the study and were not included in any of the tables except Table 27, which gives the screening levels for each of the pesticides. Initial injections of sample extract equivalent to 40 mg were necessary to attain these sensitivities. Any peak less than 10% FSD was considered a trace and was not quantitated.

TABLE 26. RECOVERIES (%) OF ADDED PESTICIDES*

	Evaporation from beaker	Evaporation from K-D	Through method	Spiked cucumbers	Spiked brine
Chloroneb	0	77	78	92	86
PCNB	15	94	92	96	85
PCA	47	96	96	104	91
Parathion	90	98	99	108	87
Paraoxon	96	100	87	106	71
Bravo [®]	88	65	99	86	--
Dacthal [®]	105	105	101	98	--
Difolatan [®]	46	70	92	95	--
Endosulfan I	95	--	92	105	87
Endosulfan II	98	--	98	107	92
Endosulfan SO ₄	97	--	97	95	91
Carbaryl	--	--	94	106	94

*Recoveries represent an average result of three or more determinations.

TABLE 27. LOWEST LEVELS AT WHICH RESIDUES WERE
QUANTITATED

Pesticide	PPM	Pesticide	PPM
Chloroneb	0.10	Dacthal	0.004
PCNB	0.002	Difoltan	0.02
PCA	0.003	Endosulfan I	0.01
Parathion	0.01	Endosulfan II	0.01
Paraoxon	0.02	Endosulfan SO ₄	0.02
Bravo	0.002	Carbaryl	0.05

Tables 28-29 indicate that carbaryl is the only one of the selected pesticides that accumulates significantly if each batch of raw cucumbers added to the tank would contain high levels of residues (Table 28, cycles 1 and 2, "heat treated brine" and "brined cucumbers"). The low residues on the raw cucumbers used in cycles 3-5 were caused by heavy rains just after the crop was sprayed with the pesticides. These unexpected low residues actually aided the study by showing that if a batch of cucumbers with low residues is brined in the tank, the levels in the brined cucumbers increased to slightly more than in the raw cucumbers and the brine levels decreased to almost trace amounts. This was probably caused by the raw cucumbers absorbing pesticides from the solutions during the brining process (Table 28, cycle 3). If several cycles of cucumbers with high residues were brined in the same tank and residues of carbaryl (or any of the pesticides tested) reached very high levels, the brine could still be salvaged by one chemical treatment. As shown in Tables 28-31, the chemical treatment procedure destroyed all detectable residues except traces of PCNB and PCA in cycle no. 2.

Pectinase Inactivation

Table 32 shows the list of organisms investigated. Table 33 shows the decimal reduction times (D-values) for the six most heat stable enzyme preparations. It was found that enzyme from Penicillium janthinellum was the most stable among those studied. Subsequent investigations of the effect of pH and salt concentration were done to determine the thermal stability under conditions which might occur in spent brines. Figure 5 shows the effect of pH on the D-value of the pectinase at 75°C (167°F) and 78°C (172.4°F). The pH of maximum stability is 3.7 at both temperatures. There is a large increase in stability with only a small change in temperature. This points up the importance of good temperature control during brine treatment. A small drop in temperature could result in inadequate brine treatment.

The effect of salt concentration on enzyme stability is shown in Table 34. The enzyme is more stable at higher salt concentrations, but the magnitude of the effect is small. The recommended process has a sufficient safety margin included so that adjustment of the process for the salt concentration of the spent brine will not be required.

The thermal stability of P. janthinellum pectinase in commercial spent brines was less than that in the simulated brines. D-values obtained in commercial brines at 12.6% NaCl and 75°C (167°F) at pH 3.5 and 3.7 were 14 sec and 18 sec, respectively. D-values in simulated brines with 12% NaCl, 0.6% lactic acid and 0.1% Ca^{++} ion were 29 sec and 33 sec at the same temperature and pH.

TABLE 28. EFFECT OF HEAT AND NaOH TREATMENT ON CARBARYL IN PICKLE BRINE (PPM)

Produce analyzed	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
Raw cucumbers (unwashed)*	2.98	5.50	0.10	0.31	N.D. [†]	1.01
(washed)	2.13	5.19	0.10	0.27	N.D.	0.97
Brined cucumbers [‡] (av. tanks 1, 3-7)	2.76	3.43	0.27	0.20	tr [§]	1.18
Untreated brine [‡] (av. tanks 1, 3-7)	0.93	1.37	0.10	No sple	No sple	0.74
Heat treated brine [‡] (av. tanks 1, 3, 4)	0.59	1.46	N.D.	0.10	tr	Not treated
Chemically treated brine (av. tanks 5-7)	N.D.	N.D.	N.D.	N.D.	N.D.	Not treated
Brined cucumbers (control tank 2)	2.66	2.46	tr	tr	tr	0.53
Untreated brine (control tank 2)	0.93	1.15	tr	Sample lost	tr	0.54

*Unwashed cucumbers used for brining.

[†]N.D. = none detected.

[‡]Tank #2 was control tank and received no treatment.

[§]tr = trace.

TABLE 29. EFFECT OF HEAT AND NaOH TREATMENT ON PARATHION IN PICKLE BRINE (PPM)

Product analyzed	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
Raw cucumbers (unwashed)* (washed)	0.07 0.09	0.04 0.03	0.04 0.03	tr [†] tr	tr [‡] N.D. [#]	0.58 0.44
Brined cucumbers [§] (av. tanks 1, 3-7)	0.07	0.03	0.02	tr	tr	0.23
Untreated brine (av. tanks 1, 3-7)	0.01	tr	tr	No sple	No sple	0.07
Heat treated brine [§] (av. tanks 1, 3, 4)	tr	tr	N.D.	N.D.	N.D.	Not treated
Chemically treated brine (av. tanks 5-7)	N.D.	N.D.	N.D.	N.D.	N.D.	Not treated
Brined cucumbers (control tank 2)	0.09	0.02	0.03	N.D.	N.D.	0.15
Untreated brine (control tank 2)	tr	tr	tr	N.D.	N.D.	0.01

*Unwashed cucumbers used for brining.

[†]tr = trace.

[#]N.D. = none detected.

[§]Tank #2 was control tank and received no treatment.

TABLE 30. EFFECT OF HEAT AND NaOH TREATMENT ON ENDOSULFAN IN PICKLE BRINE (PPM)

Product Analyzed	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
Raw cucumbers (unwashed)*	0.14, 0.12, 0.06 [†]	0.12, 0.21, 0.03	0.03, 0.02, tr [#]	tr, tr, tr	tr, tr, tr	0.30, 0.27, 0.06
Raw cucumbers (washed)	0.14, 0.13, 0.06	0.13, 0.17, 0.04	0.03, 0.01, tr	tr, tr, tr	tr, tr, tr	0.25, 0.23, 0.07
Brined cucumbers [§] (Av. Tanks 1,3-7)	0.18, 0.15, 0.07	0.12, 0.20, 0.02	0.04, 0.03, tr	tr, tr, tr	N.D., N.D., N.D. [#]	0.31, 0.28, 0.09
Untreated brine [§] (Av. Tanks 1,3-7)	0.01, 0.01, tr	tr, 0.02, tr	tr, tr, tr	No Sample	No Sample	0.08, 0.09, 0.06
Heat treated brine [§] (Av. Tanks 1,3,4)	tr, tr, tr	tr, 0.01, N.D.	N.D., N.D., N.D.	N.D., N.D., N.D.	N.D., N.D., N.D.	Not Treated
Chemically treated brine (Av. Tanks 5-7)	N.D., N.D., N.D.	N.D., N.D., N.D.	N.D., N.D., N.D.	N.D., N.D., N.D.	N.D., N.D., N.D.	Not Treated
Brined cucumbers (Control Tank 2)	0.20, 0.16, 0.07	0.12, 0.21, tr	0.06, 0.02, tr	N.D., N.D., N.D.	N.D., N.D., N.D.	0.22, 0.25, 0.03
Untreated brine (Control Tank 2)	0.01, 0.01, tr	tr, tr, N.D.	N.D., N.D., N.D.	N.D., N.D., N.D.	N.D., N.D., N.D.	0.01, 0.02, N.D.

*Unwashed cucumbers used for brining.

[†] Values represent residues of Endosulfan I, II, and SO₂ respectively.

[#] tr = Trace.

[§] Tank #2 was control tank and received no treatment.

[#] N.D. = none detected.

TABLE 31. EFFECT OF HEAT OR NaOH TREATMENT ON PCNB AND PCA IN PICKLE BRINE (PPM)

Product Analyzed	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
Raw cucumbers (unwashed) *	0.105, 0.003	0.080, 0.053	0.016, 0.013	tr, tr	N.D., N.D.	0.170, tr
Raw cucumbers (washed)	0.120, 0.004	0.043, 0.055	0.017, 0.013	tr, tr	N.D., N.D.	0.140, N.D.
Brined cucumbers (Av. Tanks 1,3-7)	0.039, 0.030	0.057, 0.078	0.018, 0.030	N.D., N.D.	N.D., N.D.	0.015, N.D.
Untreated brine (Av. Tanks 1,3-7)	N.D., N.D.	tr, 0.003	N.D., tr	No Spl	No Spl	0.005, N.D.
Heat treated brine (Av. Tanks 1,3,4)	N.D., N.D.	tr, tr	N.D., N.D.	N.D., N.D.	N.D., N.D.	Not Treated
Chemically treated brine (Av. Tanks 5-7)	N.D., N.D.	tr, tr	N.D., N.D.	N.D., N.D.	N.D., N.D.	Not Treated
Brined cucumbers (Control Tank 2)	0.037, 0.033	0.042, 0.088	0.015, 0.024	N.D., N.D.	N.D., N.D.	0.010, N.D.
Untreated brine (Control Tank 2)	tr, tr	0.005, tr	tr, tr	N.D., N.D.	N.D., N.D.	N.D., N.D.

*Unwashed cucumbers used for brining.

† Values represent residues of PCNB and PCA respectively.

‡ tr = Trace.

§ N.D. = none detected.

Tank #2 was control tank and received no treatment.

TABLE 32. SOURCES AND IDENTITY OF FUNGI USED FOR DETERMINATION OF THERMAL STABILITY OF PECTINASES IN BRINES

Organism	Source*
<u>Alternaria tenuis</u>	NRRL 2169
<u>Cladosporium cladosporioides</u>	MSU
<u>Fusarium oxysporum</u>	NRRL 1943
<u>Fusarium roseum</u>	MSU
<u>Fusarium solani</u>	NRRL 3078
<u>Penicillium janthinellum</u>	NRRL 2016
<u>Penicillium oxalicum</u>	NRRL 790
<u>Trichoderma viride</u>	MSU

*NRRL - USDA Northern Regional Research Laboratory, Peoria, IL

MSU - Michigan State University, Department of Botany and Plant Pathology.

TABLE 33. D-VALUES OF PECTINASES WITH THE GREATEST THERMAL STABILITY IN PRELIMINARY EXPERIMENTS. D-VALUES WERE OBTAINED AT pH 3.3 IN 12% NaCl, 0.6% LACTIC ACID AND 0.1% Ca⁺⁺ ION

Organism	Temperature (°C)	D-value (sec)
<u>Penicillium janthinellum</u>	78	4
	75	18
<u>Penicillium oxalicum</u>	70	18
<u>Fusarium solani</u>	70	5
<u>Fusarium oxysporum</u>	70	4
<u>Alternaria tenuis</u>	65	25
<u>Trichoderma viride</u>	65	10

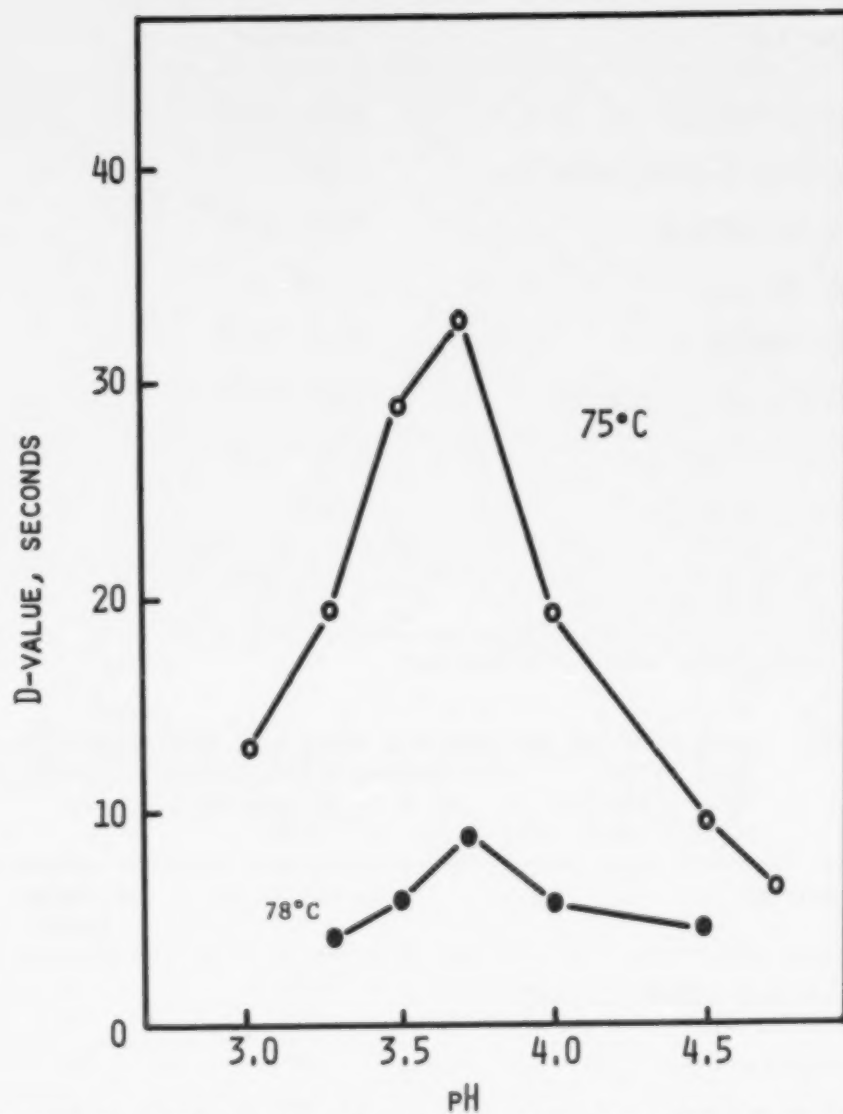


Figure 5. Effect of pH on heat inactivation of Penicillium janthinellum pectinase. Experiments were done in brine containing 12% NaCl, 0.6% lactic acid and 0.1% Ca^{++} ion.

TABLE 34. EFFECT OF NaCl CONCENTRATION ON THE HEAT INACTIVATION OF PECTINASE FROM PENICILLIUM JANTHINELLUM AT 75°C

NaCl, %	D-values at 75°C (sec)	
	pH 3.5	pH 3.7
8	24	31
12	29	33
16	30	37

TABLE 35. INACTIVATION OF PECTINASE FROM PENICILLIUM JANTHINELLUM AT HIGH pH IN SPENT BRINE. TEMPERATURE 22°C (71.6°F). SALT CONCENTRATION 8.0%

pH of incubation	Time for 90% inactivation (hr)	Time for 99% inactivation (hr)
10.6	50% inact. in 70 hr	
11.0	34	*
11.2	5.0	37
11.3	6.5	27
11.6	2.5	13 (est.)

*99% inactivation of the enzyme was not reached in 48 hr.

At 78°C (172.4°F), the maximum D-value observed under any of the conditions investigated was 8 sec. Currently, the minimum recommended process for brine treatment is 79.4°C (175°F) for 30 sec in a plate heat exchanger. This will result in at least a 30 sec/8 sec = 3.7 D process. Therefore, at 79.4°C for 30 sec, the extent of inactivation will be $10^{3.7}$ or about 5,000-fold. Since the suggested heating temperature is 1.4°C higher than the highest temperature investigated in these experiments and the pectinase was significantly less stable in commercial spent brines, the extent of enzyme inactivation in commercial brine would be expected to be considerably greater than 5,000-fold.

Pectinases are known which are considerably more resistant to thermal inactivation than *P. janthinellum* enzyme. A commercial enzyme from *Aspergillus niger* was found to have a D-value of 34 sec at 80°C (176°F) in pH 3.6 simulated spent brine (8). Archer and Fielding (32) reported a polygalacturonase from *Sclerotinia fructigena*, which caused disintegration of fruits after canning, that had a D-value near 3.5 hr when heated at 90°C in pH 7.0, 0.02 M phosphate buffer. Therefore, the possibility exists that a highly stable softening enzyme could occur in fermentation brines. However, heating at 79.4°C (175°F) for 30 sec will be sufficient to protect against softening from pectinases which are likely to be present on cucumber fruits and flowers.

Experiments were also done to determine the stability of *P. janthinellum* pectinase at the high pH levels encountered during base treatment. It was found that the enzyme could not be adequately inactivated if the temperature was held at 10°C (50°F). In northern locations, such as Michigan, chemical treatment should not be done until the brines have warmed up. In all cases pectinase inactivation at high pH did not show first order denaturation kinetics. The rate of inactivation declined with time. As a result, meaningful D-values could not be calculated. Table 35 shows the effect of different pH levels at 22°C (72°F) on the time required for 90% and 99% enzyme inactivation. Based upon these results, it is recommended that brine be held at 72°F or higher during chemical treatment. The pH should be raised to 11.2 or higher and held for at least 37 hr at that pH before acidifying the brine.

Enzymatic softening in Michigan is not common. Analysis of spent brines, according to the procedure developed by Bell and Etchells (11), after cucumbers were removed from fermentation tanks, showed no measurable pectinase activity. As a result, it was not possible to evaluate the effect of heat and chemical treatments on the inactivation of pectinase as they occurred in commercial brines.

Lysinoalanine in Base Treated Brine

Since it was known that base treatment of protein could lead to formation of lysinoalanine (26) and it had been reported that free lysinoalanine was toxic to rats (27), an experiment was done to determine whether lysinoalanine was formed during base treatment of spent brine. A sample of first cycle brine was adjusted to pH 11.4 and held at room temperature for 8 days. The clear supernatant was removed and adjusted to pH 4.6 with acetic acid. This treatment was a severe treatment relative to that required for pectinase inactivation. Lysinoalanine was found in the spent brine before treatment at a level of 15 $\mu\text{g/l}$. After treatment, 12 $\mu\text{g/l}$ were detected. The results indicated that significant amounts of lysinoalanine were not formed as a consequence of base treatment. Lysinoalanine has been found in a number of foods and food proteins (33, 34). The level in pickle brine would appear to be quite low compared to the levels in processed foods which contain significant levels of protein.

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APPENDIX

TABLE A-1. COMPOSITION OF FIRST CYCLE SPENT BRINE BEFORE
HEAT TREATMENT, 1975 DATA

Parameter	Tank number						
	K7	K11	K41	L8	L39	L40	L43
Acid % lactic	.319	.577	.360	.420	.480	.412	.501
Salt %	12.10	12.96	10.92	14.02	14.10	13.64	14.28
pH	3.52	3.52	3.57	3.68	3.58	3.57	3.68
Sugar mg/l	325	585	306	404	391	427	403
SS mg/l	238	240	200	300	300	185	320
BOD mg/l	7550	14000	8250	10500	9800	10450	11700
COD mg/l	12745	15900	11235	14195	16500	13855	15025
Kjeldahl N mg/l	517	738	499	597	712	612	530
Cd mg/l	.031	--	.013	0	.016	.005	.027
Hg mg/l	0	0	0	0	0	0	0
P mg/l	119	154	102	131	142	114	148
Ca mg/l	1010	980	910	980	1090	930	1170
Mg mg/l	130	150	130	130	160	140	150
Mn mg/l	3.6	3.0	3.3	2.4	1.9	1.1	3.6
Fe mg/l	4.9	7.5	4.9	7.5	6.9	3.7	8.1
Cu mg/l	--	1.8	1.7	1.7	1.5	0.9	2.0
B mg/l	1.4	1.8	1.3	1.4	1.3	1.0	1.6
Zn mg/l	6.8	5.4	5.1	4.7	3.8	2.8	5.6
Al mg/l	6.3	5.3	5.3	4.7	5.3	4.2	6.3
Cr mg/l	.012	.001	0	0	0	0	.010

TABLE A-2. COMPOSITION OF FIRST CYCLE SPENT BRINE
AFTER HEAT TREATMENT, 1975 DATA

Parameter	Tank number					
	K7	K41	K41	L8	L39	L40
Acid % lactic	.087	.111	.208	.074	.229	.331
Salt %	12.50	11.00	11.16	12.20	14.38	13.96
pH	4.72	4.73	4.39	5.02	4.45	4.76
Sugar mg/l	228	273	276	123	271	463
SS mg/l	138	273	195	100	336	185
BOD mg/l	10375	8700	9250	7825	12000	10300
COD mg/l	13080	11560	11815	10825	15460	13910
Kjeldahl N mg/l	559	495	500	395	--	585
Cd mg/l	.008	0	.016	0	.179	.027
Hg mg/l	0	0	0	0	0	0
P mg/l	119	102	91	80	148	131
Ca mg/l	1060	910	810	960	1060	1040
Mg mg/l	130	120	120	100	150	150
Mn mg/l	3.6	3.3	1.1	3.3	3.3	1.9
Fe mg/l	8.7	7.5	5.8	4.9	9.0	6.4
Cu mg/l	1.8	1.8	1.2	2.1	1.6	1.2
B mg/l	1.7	1.3	1.0	1.0	1.7	1.5
Zn mg/l	5.8	5.1	2.6	5.1	4.4	3.3
Al mg/l	17	9.0	7.4	13.8	15.9	11.6
Cr mg/l	0	.003	.003	0	.010	0

TABLE A-3. COMPOSITION OF FIRST CYCLE SPENT BRINE
BEFORE CHEMICAL TREATMENT, 1975 DATA

Parameter	Tank number				
	K10	L6	L9	L42	M8
Acid % lactic	.398	.334	.410	.563	.650
Salt %	13.29	13.39	14.11	14.66	10.86
pH	3.48	3.46	3.66	3.58	3.50
Sugar mg/l	408	305	490	484	280
SS mg/l	125	300	310	267	155
BOD mg/l	9850	7850	10200	12300	12560
COD mg/l	13620	10545	13820	16135	16085
Kjeldahl N mg/l	486	--	600	637	536
Cd mg/l	.162	--	.013	.179	.019
Hg mg/l	0	0	0	0	0
P mg/l	114	102	125	114	125
Ca mg/l	930	1040	1060	1010	1060
Mg mg/l	120	130	130	130	140
Mn mg/l	2.7	3.3	2.7	3.8	4.4
Fe mg/l	4.6	7.8	6.9	8.1	8.4
Cu mg/l	2.0	1.9	1.6	2.2	2.3
B mg/l	1.2	1.5	1.3	1.3	1.6
Zn mg/l	4.2	4.9	4.4	5.6	5.8
Al mg/l	5.3	5.3	4.7	7.9	7.4
Cr mg/l	.012	0	0	.003	0

TABLE A-4. COMPOSITION OF FIRST CYCLE SPENT BRINE
AFTER CHEMICAL TREATMENT, 1975 DATA

Parameter	Tank number				
	L41	L42	L47	M45	L7
Acid % lactic	.415	.289	.208	.058	.192
Salt %	10.38	10.60	14.07	13.50	14.37
pH	4.60	4.55	5.10	5.25	5.00
Sugar mg/l	151	170	349	194	242
SS mg/l	35	55	22	110	53
BOD mg/l	12300	15750	16625	8750	16650
COD mg/l	15665	18265	21620	12700	17795
Kjeldahl N mg/l	457	516	616	432	594
Cd mg/l	.023	.001	.009	.098	.159
Hg mg/l	0	0	0	0	0
P mg/l	11	28	34	17	40
Ca mg/l	570	470	810	810	910
Mg mg/l	10	20	10	10	10
Mn mg/l	0.5	0.5	2.4	2.2	4.1
Fe mg/l	1.7	2.9	2.0	1.4	4.6
Cu mg/l	0.7	0.4	1.4	1.6	2.2
B mg/l	1.0	0.7	1.6	1.1	1.8
Zn mg/l	1.7	1.3	3.8	3.8	5.4
Al mg/l	6.4	7.9	6.3	13.8	23.5
Cr mg/l	0	0	0	.003	0

TABLE A-5. COMPOSITION OF 2ND CYCLE SPENT BRINE BEFORE
AND AFTER HEAT TREATMENT, 1976 DATA

Parameter	Tank number							
	Before treatment				After treatment			
	L46	M4	M8	M10	M49	M4	M3	L44
Acid % lactic	.57	.66	.63	.61	.20	.22	.30	.12
Salt %	10.7	11.5	11.9	11.6	12.3	11.8	11.8	11.5
pH	3.52	3.55	3.52	3.50	4.58	4.49	4.33	5.10
Sugar mg/l	230	276	319	227	232	205	262	189
SS mg/l	157	160	252	622	220	100	194	313
BOD mg/l	10700	13400	13500	12400	13200	12363	14000	16600
COD mg/l	17592	19768	19504	17576	18724	18720	20128	19616
Kjeldahl N mg/l	540	641	614	540	631	571	669	613
Cd mg/l	.03	.03	.01	.03	.02	.02	.03	.025
Hg mg/l	.003	.003	.003	.003	.003	.004	.003	.003
P mg/l	119	165	159	114	159	108	137	108
Ca mg/l	910	1090	1110	1060	1220	1220	1140	1010
Mg mg/l	170	180	180	160	190	180	180	180
Mn mg/l	0.5	1.1	2.4	1.6	1.6	1.6	2.4	1.1
Fe mg/l	3.4	14.7	11.7	7.5	9.9	5.8	23.9	5.2
Cu mg/l	0.8	1.1	2.0	1.7	1.8	1.5	1.6	1.4
B mg/l	1.1	1.3	1.5	1.5	1.5	1.6	1.7	1.5
Zn mg/l	2.8	4.0	6.6	5.6	5.4	5.4	7.3	4.4
Al mg/l	3.2	9.0	10.0	11.1	20.2	7.4	14.3	6.3

TABLE A-6. COMPOSITION OF 2ND CYCLE SPENT BRINE BEFORE
AND AFTER CHEMICAL TREATMENT, 1976 DATA

Parameter	Tank number							
	Before treatment				After treatment			
	L47	M6	M43	M48	L47	M5	M11	M5
Acid % lactic	.65	.57	.57	.74	.04	.31	.24	.43
Salt %	9.6	11.3	12.3	11.2	10.0	10.4	11.6	11.4
pH	3.60	3.82	3.58	3.67	6.65	4.80	4.90	4.80
Sugar mg/l	292	259	228	253	87	90	104	178
SS mg/l	179	167	117	170	104	208	14	22
BOD mg/l	13300	12700	13600	18400	18817	14800	15921	19840
COD mg/l	18552	19544	18032	21704	18667	23152	22368	26952
Kjeldahl N mg/l	453	608	590	838	465	543	489	531
Cd mg/l	.025	.02	.03	.02	.01	.05	.03	.03
Hg mg/l	.003	.003	.003	--	.003	.003	.003	.003
P mg/l	85	97	102	114	11	11	11	11
Ca mg/l	760	1010	1010	1060	640	590	810	570
Mg mg/l	100	160	140	160	10	10	0	0
Mn mg/l	0.5	1.1	1.1	1.1	0.5	0.3	1.1	0.5
Fe mg/l	20.5	15.9	17.7	15.9	1.1	2.3	2.6	13.5
Cu mg/l	0.8	0.8	1.7	0.8	1.7	1.3	1.4	2.0
B mg/l	0.9	1.5	1.4	1.5	1.3	1.5	1.5	1.7
Zn mg/l	3.1	4.4	4.7	4.4	3.3	2.6	4.2	4.4
Al mg/l	4.2	4.7	14.8	4.7	32.8	21.3	36.1	34.4

TABLE A-7. ANALYSIS OF 1ST CYCLE CONTROL SPENT
BRINES AFTER REMOVAL OF SALT STOCK

Tank no. -1975-	Acid %	Salt %	pH	Reducing sugar mg/l	BOD mg/l	COD mg/l	Suspended solids mg/l
L36	.670	8.6	3.30	378	11480	15736	227
M2	.742	9.7	3.40	575	15900	20296	540
M51	.640	10.5	3.35	571	15010	15864	463
M1	.657	12.1	3.32	125	13800	17520	488
M52	.669	8.5	3.39	193	13657	16525	160
M9	.761	10.2	3.29	493	17000	18880	311
M42	.649	8.4	3.38	481	11375	18500	--
M35	.718	9.6	3.38	505	17200	19260	388
M33	.716	9.7	3.37	168	21400	18575	288
L48	.498	8.7	3.50	176	10000	14825	213
<u>-1976-</u>							
M7	.568	9.3	3.52	172	14000	16990	347
M50	.514	8.1	3.62	134	10800	14309	820
M47	.782	10.2	3.57	258	18800	23550	480
M46	.557	7.7	3.60	208	14558	18116	730
M6	.579	9.4	3.50	203	12000	17184	961
M43	.520	7.6	3.60	166	11612	15131	420
M9	.415	6.7	3.50	140	6600	12210	127
M8	.629	9.5	3.49	210	12000	19066	535

TABLE A-8. ANALYSIS OF 2ND AND 3RD CYCLE HEAT TREATMENT
SPENT BRINES AFTER REMOVAL OF SALT STOCK

Tank no. -1975- (2nd cycle)	Acid %	Salt %	pH	Reducing sugar mg/l	BOD mg/l	COD mg/l	Suspended solids mg/l
L37	.628	10.2	3.43	467	13480	16584	76
M3	.892	8.8	3.50	479	20200	25600	967
M49	.564	12.2	3.50	527	13600	16730	1025
M47	.732	10.2	3.60	76	19000	21695	675
M5	.623	8.7	3.67	420	6820	17824	765
M7	.534	9.0	3.51	370	9320	15584	124
M10	.749	12.0	3.52	499	21400	23535	500
M41	.852	12.2	3.25	361	10200	11390	330
M11	.645	11.3	3.45	531	18700	20170	750
M8	.702	9.3	3.48	431	12720	19112	207
L46	.551	7.7	3.55	402	12400	17180	660
 -1976- (3rd cycle)							
M1	.751	7.3	3.64	179	18763	22935	175
M52	.767	12.6	3.62	181	20400	25555	771
M3	.833	9.7	3.62	192	20400	27184	617
M44	.738	9.9	3.64	186	18400	24506	732
M49	.887	9.6	3.80	172	23800	27776	271
M42	.750	11.5	3.60	186	21400	25396	230
M4	.824	10.1	3.55	191	19600	24850	185
L48	.371	6.5	3.83	119	11000	12846	53

TABLE A-9. ANALYSIS OF 2ND AND 3RD CYCLE CHEMICALLY TREATED
SPENT BRINES AFTER REMOVAL OF SALT STOCK

Tank no. -1975- (2nd cycle)	Acid %	Salt %	pH	Reducing sugar mg/l	BOD mg/l	COD mg/l	Suspended solids mg/l
L44	.852	10.6	3.50	512	17600	23288	172
M4	.787	8.8	3.62	169	17000	23490	--
M50	.642	10.0	3.65	380	15800	18910	457
M48	.890	10.8	3.65	431	20300	24815	417
M6	.755	9.6	3.63	410	14520	22104	136
M43	.697	8.4	3.58	442	13250	18732	--
M40	.723	9.6	3.38	69	17300	18945	275
M39	.636	10.1	3.60	71	17000	18055	380
M45	.594	9.1	3.70	342	14800	16604	144
L47	.750	7.3	3.59	420	15600	19670	139
 -1976- (3rd cycle)							
M2	.937	7.7	3.78	258	21000	26082	367
M51	.507	9.1	3.73	162	13000	15667	1610
M48	.978	10.6	3.78	350	25400	32323	880
M45	.538	7.6	3.70	208	13275	16351	660
M5	1.14	10.2	3.65	328	27200	30784	820
M41	.505	7.2	3.72	184	13600	15028	387
M11	.770	8.6	3.41	311	21000	23508	90
L47	.806	8.8	3.58	274	22600	25068	80

TABLE A-10. SALT STOCK QUALITY OF CUCUMBERS FERMENTED IN FRESH SALT BRINE, HEAT TREATED 3RD CYCLE BRINE AND CHEMICALLY TREATED 3RD CYCLE BRINE--1976 SEASON

Group no.*	Fresh brine control			Heat treated brine			Chemically treated brine		
	Good [†] %	CA [‡] %	CU [§] %	Good %	CA %	CU %	Good %	CA %	CU %
1	29.3	72.6	27.4	31.0	75.6	24.4	47.9	84.4	15.6
2	73.8	95.9	4.1	48.4	82.9	17.1	70.2	94.1	5.9
3	73.9	91.3	8.7	50.7	85.5	14.5	64.3	89.9	10.1
4	49.5	82.6	17.4	32.6	62.8	37.2	34.8	69.0	31.0
5	30.0	74.2	25.8	65.0	91.5	8.5	55.5	80.8	19.2
6	35.3	77.0	23.0	22.7	64.5	35.5	54.5	78.3	21.7
7	71.4	98.5	1.5	74.3	94.3	5.7	67.4	100	0
8	53.4	87.1	12.9	45.3	80.8	19.2	38.0	86.8	13.2

*All tanks in a group were filled on the same day.

[†]Good stock is free of internal defects.

[‡]CA, commercially acceptable. Includes sum of good stock and stock with slight defects.

[§]CU, commercially unacceptable. Stock with severe internal defects. Useful only for relish products.

TABLE A-11. SALT STOCK QUALITY OF CUCUMBERS FERMENTED IN FRESH SALT BRINE,
HEAT TREATED 2ND CYCLE BRINE AND CHEMICALLY TREATED 2ND CYCLE BRINE--1975 SEASON

Group no.*	Fresh brine control			Heat treated brine			Chemically treated brine		
	Good† %	CA‡ %	CU§ %	Good %	CA %	CU %	Good %	CA %	CU %
1	30.0	46.1	53.9	52.7	76.3	23.7	54.8	71.4	28.6
2	73.8	91.5	8.5	77.8	84.1	15.9	56.8	71.8	28.2
3	74.5	87.0	13.0	87.1	97.5	2.5	82.8	96.5	3.5
4	84.3	96.3	3.7	66.6	85.6	14.4	75.9	89.6	10.4
5	71.0	84.0	16.0	68.7	88.0	12.0	58.2	72.3	27.7
6	79.8	89.1	10.9	69.0	77.6	22.4	--	--	--
7	78.6	92.1	7.9	85.9	96.5	3.5	88.6	93.6	6.4
8	71.3	87.0	13.0	85.3	96.3	3.7	82.1	95.0	5.0
9	82.4	91.6	8.4	87.0	97.2	2.8	68.1	88.1	11.9
10	--	--	--	52.2	78.1	21.9	75.3	90.0	10.0
11	82.0	88.3	11.7	68.0	74.3	25.7	87.8	96.9	3.1

*All tanks in a group were filled on the same day.

†Good stock is free of internal defects.

‡CA, commercially acceptable. Includes sum of good stock and stock with slight defects.

§CU, commercially unacceptable. Stock with severe internal defects. Useful only for relish products.

TABLE A-12. MINERAL COMPOSITION OF SPENT BRINE FROM 1ST CYCLE CONTROL
FERMENTATION--1975 DATA. ALL RESULTS ARE EXPRESSED IN mg/l IN BRINE

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb	Cr
1	467	.002	0	114	910	120	3.0	5.5	1.2	1.2	4.2	5.3	0	0
2	---	.107	0	165	1490	170	3.5	14.2	1.8	1.6	5.3	12.2	0	-
3	560	0	0	91	1060	120	2.2	5.8	1.1	1.1	3.5	4.7	0	0
4	589	.004	0	153	1480	160	3.3	20.3	1.7	1.6	4.9	10.9	0	0
5	603	.040	0	148	1110	140	2.7	7.2	1.4	1.2	4.4	6.8	0	0
6	644	.024	0	159	1220	160	2.7	9.0	2.0	1.5	3.8	10.0	0	0
7	---	---	.002	---	---	---	---	---	---	---	---	---	-	-
8	641	.007	0	119	1050	140	2.1	6.8	1.1	1.0	3.4	7.3	0	0
9	611	0	0	159	1330	150	4.7	10.5	2.0	1.7	6.1	9.0	0	0
10														
11	543	0	0	114	960	130	2.7	6.4	1.3	1.2	3.5	6.8	0	0

TABLE A-13. MINERAL COMPOSITION OF SPENT BRINE FROM 2ND CYCLE HEAT TREATED FERMENTATION--1975 DATA. ALL RESULTS ARE EXPRESSED IN mg/l IN BRINE

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb	Cr
1	625	.002	0	137	1110	140	3.3	6.1	1.5	1.5	4.9	4.7	0	0
2	1013	.017	0	202	1060	160	2.4	25.8	1.4	1.4	5.6	30.5	0	0
3	504	.001	0	137	1220	150	4.4	15.3	2.4	1.7	6.3	17.5	0	0
4	886	.005	0	182	1060	160	2.2	21.4	1.8	1.3	4.2	21.8	0	0
5	705	.036	0	159	1040	160	2.7	12.6	1.6	1.3	4.7	12.2	0	0
6	605	.016	0	131	930	140	1.6	8.1	1.0	1.0	3.1	6.3	0	0
7	849	.016	0	173	1020	160	3.1	8.4	1.9	1.4	5.1	11.3	0	0
8	221	0	0	68	1250	105	3.4	6.0	2.4	1.6	4.9	7.1	0	0
9	769	0	0	154	1170	150	4.4	12.0	2.3	1.6	5.4	18.1	0	0
10	524	.038	0	134	935	150	1.9	9.3	1.1	1.1	4.9	6.8	0	0
11	515	0	0	102	710	130	1.1	3.7	0.7	0.8	2.2	6.8	0	0

TABLE A-14. MINERAL COMPOSITION OF SPENT BRINE FROM 2ND CYCLE CHEMICAL TREATMENT
FERMENTATION--1975 DATA. ALL RESULTS ARE EXPRESSED IN mg/l IN BRINE

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb	Cr
1	839	.004	.005	80	810	90	1.4	3.4	0.8	0.9	2.2	9.0	0	0
2	---	---	.002	--	---	--	2.2	---	---	1.9	---	---	-	-
3	647	0	.015	119	1060	130	1.9	10.2	1.2	1.3	4.0	9.5	0	0
4	835	.002	0	162	1025	130	2.5	2.6	1.6	1.4	4.1	---	0	0
5	711	.020	0	131	910	110	2.4	5.8	1.2	1.2	4.0	21.5	0	0
6														
7	---	---	---	---	---	---	---	---	2.0	---	4.7	7.9	-	-
8	292	0	0	137	1300	130	2.2	14.1	1.6	1.5	3.8	4.3	0	-
9	603	0	0	137	1190	130	3.8	12.0	1.9	1.7	6.1	9.5	0	0
10	506	.022	.002	102	910	100	1.4	5.5	1.0	1.0	2.2	6.8	0	0
11	886	.006	0	125	860	120	1.9	6.9	1.0	1.1	2.8	7.4	0	0

TABLE A-15. MINERAL COMPOSITION OF SALT STOCK CUCUMBERS FROM 1ST CYCLE CONTROL
FERMENTATION--1975 DATA. ALL RESULTS ARE EXPRESSED AS mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb	Cr
1	822	.167	.002	114	960	120	1.1	3.7	0.6	1.3	2.2	1.0	0	0
2	852	.066	.005	159	1440	160	3.3	16.5	2.0	2.0	4.7	13.8	0	.023
3	788	.040	.005	125	1220	130	1.6	8.7	1.3	1.5	4.0	8.4	0	0
4	688	0	.005	119	1110	130	1.4	18.9	1.0	1.5	3.1	13.2	0	0
5	735	.073	.003	148	60	130	2.7	8.1	1.6	1.7	4.4	6.3	0	.003
6	181	.069	.002	148	1125	140	2.3	9.1	1.5	1.7	4.1	2.7	0	.018
7	83	.045	.002	151	1170	165	1.9	8.5	1.3	1.6	3.4	7.1	0	.018
8	326	.030	.010	125	1050	130	0.8	7.8	0.8	1.2	2.2	8.4	0	0
9	732	.039	.020	131	1330	130	1.9	11.1	1.2	1.5	3.5	9.0	0	0
10														
11	709	.038	0	125	910	130	1.4	7.5	0.9	1.3	2.6	5.3	0	.031

TABLE A-16. MINERAL COMPOSITION OF SALT STOCK CUCUMBERS FROM 2ND CYCLE HEAT TREATMENT FERMENTATION--1975 DATA. ALL RESULTS ARE EXPRESSED AS mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb	Cr
1	167	.032	.001	154	1140	150	2.2	5.8	1.2	1.7	3.8	3.7	0	0
2	---	----	----	----	----	----	----	----	1.3	1.4	5.6	30.5	-	-
3	85	.032	.010	137	1170	140	2.7	12.6	1.7	1.7	4.2	12.2	0	0
4	1090	.021	.010	211	1220	190	2.2	25.5	1.5	1.8	4.7	17.5	0	0
5	779	.012	.022	171	1060	150	2.2	14.1	1.9	1.8	3.8	12.2	0	0
6	292	.034	0	148	1250	160	2.7	8.4	1.7	1.7	4.9	7.4	0	0
7	386	.042	.007	74	320	40	0.5	15.0	0.7	0.9	1.1	19.7	0	.018
8	397	.045	.002	80	1110	90	2.7	7.8	1.6	1.7	4.2	9.0	0	.006
9	769	.063	.010	154	1040	150	1.6	8.7	1.5	1.6	3.5	9.0	0	.069
10	340	.048	.010	133	825	130	1.9	9.0	1.1	1.3	2.8	8.2	0	.031
11	350	.023	.002	114	495	135	1.2	7.8	0.7	1.3	2.5	6.5	0	0

TABLE A-17. MINERAL COMPOSITION OF SALT STOCK CUCUMBERS FROM 2ND CYCLE CHEMICAL TREATMENT FERMENTATION--1975 DATA. ALL RESULTS ARE EXPRESSED AS mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb	Cr
1	700	.062	.012	32	1090	110	2.2	5.5	1.4	1.7	3.8	3.2	0	.003
2	130	.062	.002	116	1270	140	2.2	12.6	1.4	1.9	4.4	11.6	0	.069
3	863	.035	.087	74	1110	120	3.0	11.7	1.8	1.9	4.7	7.4	0	0
4	839	.040	.010	132	810	100	2.2	23.9	1.2	1.5	3.8	13.2	0	0
5	881	.155	.012	93	980	100	2.4	7.5	1.4	1.7	4.0	9.3	0	.012
6														
7	1006	.041	.007	84	1010	130	2.7	8.4	2.0	1.7	4.7	8.4	0	.043
8	303		.020	143	1040	100	1.6	12.6	1.2	1.5	3.5	14.3	0	--
9	760	.041	.001	90	1040	120	1.6	9.6	1.2	1.5	3.5	9.0	0	.006
10	1036	.034	0	143	880	100	1.1	8.1	1.2	1.3	2.4	14.3	0	.002
11	773	.050	.007	84	910	110	3.0	8.4	2.5	1.7	4.4	8.4	0	.021

TABLE A-18. MINERAL COMPOSITION OF DESALTED CUCUMBERS FROM 1ST CYCLE CONTROL
FERMENTATION--1975 DATA. ALL RESULTS EXPRESSED IN mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb	Cr
1	409	.026	.007	40	275	55	0	2.0	0	0.4	0	0	0	.003
2	404	.019	.045	62	440	65	0	7.5	0.6	0.6	0	5.0	0	0
3	452	.045	.007	68	500	80	0	5.8	0.2	0.6	0.2	3.7	0	.028
4	372	.017	.040	57	380	60	0	13.5	1.5	0.6	0.4	8.4	0	0
5	378	.066	.008	68	430	60	0.5	6.7	0.8	0.7	0.9	31.1	0	.064
6	451	.117	.010	63	470	60	0.5	5.8	1.6	0.6	0.9	5.8	0	0
7	448	.018	.010	68	430	70	0	5.5	1.0	0.7	0.4	4.2	0	0
8	385	.025	0	34	210	30	0	5.8	0.5	0.4	0	5.3	0	0
9	379	.020	.010	57	360	50	0	4.9	0.7	0.6	0.4	5.3	0	0
10														
11	312	.113	.011	51	320	60	0	3.4	0.7	0.6	0	4.2	0	.064

TABLE A-19. MINERAL COMPOSITION OF DESALTED CUCUMBERS FROM 2ND CYCLE HEAT TREATMENT FERMENTATION--1975 DATA. ALL RESULTS ARE EXPRESSED IN mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb	Cr
1	398	.138	.005	63	360	70	0	7.9	0	0.5	0	0.5	0	.031
2	355	.020	.010	80	430	60	1.1	10.8	1.3	0.9	1.3	7.9	0	0
3	361	.022	.005	57	380	50	0.3	9.9	0.8	0.7	1.1	7.4	0	0
4	390	.018	.008	60	260	50	0.2	11.1	0.6	0.5	0.6	9.8	0	0
5	568	.352	.030	80	430	80	0.3	8.4	0.9	0.7	1.1	5.3	0	.064
6	454	.215	.037	68	430	70	0	4.0	0.7	0.6	0.9	3.7	0	0
7	82	.020	.007	34	120	20	0	11.7	1.2	0.4	0	12.2	0	0
8	323	.017	.100	40	410	50	0.5	5.8	0.8	0.7	0.6	4.2	0	0
9	311	.019	.005	57	250	60	0	5.2	0	0.4	0	3.2	0	0
10	409	.190	0	60	350	60	0	5.5	0.5	0.6	0.1	6.0	0	.032
11	351	.125	0	51	300	60	0.3	4.6	0.8	0.6	0.9	13.8	0	.002

TABLE A-20. MINERAL COMPOSITION OF DESALTED CUCUMBERS FROM 2ND CYCLE CHEMICAL TREATMENT FERMENTATION--1975 DATA. ALL RESULTS ARE EXPRESSED IN mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb	Cr
1	391	.129	.002	46	430	60	0	2.9	0.4	0.6	0.4	3.2	0	0
2	377	.029	.020	57	320	50	0	9.3	0.5	0.4	0	5.3	0	.031
3	350	.008	.350	57	360	60	0	6.1	0.3	0.6	0.2	4.7	0	0
4	314	.026	.002	57	300	50	0	16.2	0.7	0.8	0	8.4	0	0
5	318	.201	.027	57	360	50	0	2.9	1.2	0.6	0.4	3.7	0	.090
6														
7	430	.041	0	46	270	50	0	2.9	0.8	0.6	0	6.8	0	0
8	286	.032	.007	46	320	50	0.5	5.8	0.8	0.7	0.6	4.2	0	0
9	398	.028	.007	46	300	50	0	4.0	0.5	0.4	0	3.2	0	0
10	206	.097	.017	40	320	40	0.7	5.2	0.6	0.5	1.0	12.4	0	.064
11	410	.079	0	63	320	60	0	4.0	0.4	0.6	0	4.2	0	0

TABLE A-21. MINERAL COMPOSITION OF SPENT BRINE FROM 1ST CYCLE CONTROL FERMENTATION--1976 DATA. ALL RESULTS ARE EXPRESSED IN mg/l IN BRINE

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb
1	445	.035	.007	80	610	110	1.1	7.2	0.7	1.1	3.5	8.4	0
2	574	.010	.011	336	1150	250	1.7	9.5	0.1	2.0	3.0	20.2	0
3	813	.005	.001	389	1560	310	2.3	17.9	0.01	2.1	3.9	13.3	0
4	553	.010	.002	114	610	130	0.8	7.5	0.7	0.9	2.8	8.4	0
5	428	0	.011	232	820	200	0.1	5.4	0.01	0.9	0.5	5.1	0
6	659	.010	.013	232	870	220	0.3	5.7	0.7	1.3	2.1	6.9	0
7	386	----	.009	286	1030	220	1.1	32.2	0.01	1.4	2.0	27.8	0
8	483	.013	.011	322	1010	270	2.8	10.1	1.0	1.6	4.9	6.9	0

TABLE A-22. MINERAL COMPOSITION OF SPENT BRINE FROM 3RD CYCLE HEAT TREATED
FERMENTATION--1976 DATA. ALL RESULTS ARE EXPRESSED IN mg/l IN BRINE

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb
1	896	.010	.010	375	1800	300	1.6	27.7	0.02	2.2	3.9	41.7	0
2	559	.010	.009	159	660	170	1.4	10.8	1.2	1.1	3.8	17.0	0
3	998	.025	.006	375	1930	360	2.8	19.1	0.8	2.1	8.0	25.3	0
4	271	.020	.010	384	1430	360	3.4	22.1	2.1	2.0	7.3	29.0	0
5	921	.015	.010	322	1470	240	2.0	21.5	3.3	2.0	3.9	29.0	0
6	857	.030	.009	438	1840	390	1.1	18.5	0.7	2.1	3.6	24.0	0
7	799	.025	.015	393	1650	180	2.8	19.7	0.01	2.1	4.7	8.8	0
8	745	.023	.014	131	350	90	1.1	3.8	0.5	0.6	2.5	3.7	0

TABLE A-23. MINERAL COMPOSITION OF SPENT BRINE FROM 3RD CYCLE CHEMICAL TREATMENT
FERMENTATION--1976 DATA. ALL RESULTS ARE EXPRESSED IN mg/l IN BRINE

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb
1	506	.005	.013	80	660	120	0.5	7.2	1.2	1.3	2.8	10.6	0
2	882	.010	0	232	1310	200	1.9	16.7	2.0	1.8	3.0	65.7	0
3	962	.020	.006	332	1490	240	1.7	22.1	1.7	2.0	3.3	65.7	0
4	633	.010	.005	68	540	100	0.3	2.9	0.8	0.9	1.5	4.7	0
5	862	.015	.004	344	1200	270	4.0	11.9	2.1	2.1	7.3	20.2	0
6	430	.030	.002	74	520	100	2.2	4.6	1.3	0.9	2.4	18.1	0
7	475	.025	.008	82	190	60	0.3	9.4	0.5	0.6	0.6	9.3	0
8	786	.035	.002	120	260	80	0.3	3.5	0.5	0.6	1.3	6.9	0

TABLE A-24. MINERAL COMPOSITION IN SALT STOCK CUCUMBERS FROM 1ST CYCLE CONTROL FERMENTATION--1976 DATA. ALL RESULTS ARE EXPRESSED IN mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb
1	540	.010	.001	91	745	110	1.1	9.3	1.0	1.4	3.7	9.3	0
2	802	.005	.003	384	1010	240	1.7	14.9	1.7	2.0	0.5	17.0	0
3	1008	.015	.002	393	1260	300	2.3	20.0	1.8	2.1	3.9	16.4	0
4	642	.013	.012	108	720	125	0.8	10.3	0.9	1.3	3.4	8.0	0
5	699	.030	.001	295	1010	250	1.4	9.5	1.2	1.8	3.2	13.9	0
6	616	.020	.005	241	1010	190	1.7	8.9	1.3	1.8	3.0	15.9	0
7	855	.010	.003	152	570	100	1.1	12.8	1.8	1.3	1.4	15.2	0
8	806	.010	.001	322	1310	270	2.0	22.4	3.4	2.1	4.7	22.1	0

TABLE A-25. MINERAL COMPOSITION IN SALT STOCK CUCUMBERS 3RD CYCLE HEAT TREATMENT FERMENTATION--1976 DATA. ALL RESULTS ARE EXPRESSED IN mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb
1	896	.020	.005	357	1700	270	2.8	25.1	1.9	2.4	5.6	26.5	0
2	863	.020	0	277	1470	310	3.4	24.2	2.4	2.0	5.2	29.7	0
3	707	.013	.005	398	1400	330	4.0	26.3	2.0	2.6	4.4	18.9	0
4	788	.020	.003	331	1330	280	2.6	18.5	1.3	2.2	5.4	16.4	0
5	351	0	.007	349	1540	300	2.3	18.8	1.7	2.2	4.4	15.2	0
6	843	.005	.001	357	1380	290	2.3	13.7	1.6	2.2	4.3	16.4	0
7	946	.015	.002	366	1290	330	1.7	47.1	2.2	2.1	0	55.6	0
8	971	.015	.003	131	360	90	0.8	4.6	0.5	0.8	2.2	3.7	0

TABLE A-26. MINERAL COMPOSITION IN SALT STOCK CUCUMBERS 3RD CYCLE CHEMICAL TREATMENT FERMENTATION--1976 DATA. ALL RESULTS ARE EXPRESSED IN mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb
1	640	.013	.004	246	730	105	1.0	8.0	0.9	1.5	3.5	8.5	0
2	1203	.025	.003	82	1330	220	1.1	16.7	1.1	2.1	3.3	20.2	0
3	941	.013	.007	322	1330	240	2.8	20.0	2.2	2.4	5.9	21.5	0
4	647	.010	.009	91	690	105	0.7	9.8	1.6	1.4	2.9	12.3	0
5	924	.020	0	340	1380	270	2.6	14.0	1.4	2.3	5.6	11.4	0
6	442	.023	.002	63	530	80	0.4	4.8	0.8	1.1	2.0	5.3	0
7	675	.030	.006	88	190	50	0.7	11.4	0.5	0.8	2.1	10.6	0
8	1037	.030	.002	114	300	60	0.6	4.4	0.6	0.8	2.0	3.4	0

TABLE A-27. MINERAL COMPOSITION IN DESALTED CUCUMBERS FROM 1ST CONTROL FERMENTATION--1976 DATA. ALL RESULTS ARE EXPRESSED IN mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb
1	542	.008	.005	170	520	120	1.7	11.9	1.3	1.4	3.3	15.2	0
2	440	.015	.005	246	520	140	0.1	6.6	1.3	0.8	0	11.4	0
3	675	.015	0	214	820	170	1.1	10.1	1.1	1.6	2.4	10.7	0
4	600	.013	.012	170	570	140	0.6	11.0	0.9	1.1	1.7	12.0	0
5	527	.010	.005	174	450	140	0.1	7.8	0.2	1.0	0	8.8	0
6	728	0	.002	349	1200	270	2.6	58.8	2.2	2.0	3.3	83.3	0
7	602	.025	.002	179	570	140	0.1	29.2	1.3	1.3	0	29.7	0
8	604	.015	0	179	720	130	0.9	14.9	1.4	1.4	2.0	18.9	0

TABLE A-28. MINERAL COMPOSITION IN DESALTED CUCUMBERS FROM 3RD CYCLE HEAT TREATED FERMENTATION--1976 DATA. ALL RESULTS ARE EXPRESSED AS mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb
1	843	0	.003	268	1060	200	1.7	20.9	1.6	1.8	3.0	16.4	0
2	531	.015	.001	357	1060	240	2.3	13.4	1.9	2.2	4.4	19.6	0
3	813	0	.001	219	1360	340	0.1	19.1	0.6	1.6	0.8	14.5	0
4	698	.015	.002	206	790	180	0.9	11.9	1.1	1.4	1.9	10.1	0
5	770	.010	.003	214	870	160	0.3	16.7	1.5	1.5	0	24.0	0
6	571	.005	.002	197	620	160	0.1	9.5	0.9	1.3	1.0	14.5	0
7	696	.015	.006	201	840	170	0.6	33.4	1.3	1.5	1.4	39.8	0
8	503	.010	.011	62	700	40	0.4	3.8	0.5	0.4	1.1	4.2	0

TABLE A-29. MINERAL COMPOSITION IN DESALTED CUCUMBERS FROM 3RD CYCLE CHEMICAL TREATED FERMENTATION--1976 DATA. ALL RESULTS ARE EXPRESSED IN mg/kg IN CUCUMBERS

Group no.	N	Cd	Hg	P	Ca	Mg	Mn	Fe	Cu	B	Zn	Al	Pb
1	528	.010	.003	161	470	110	1.4	8.4	4.9	1.6	3.2	12.6	0
2	835	.010	.008	214	910	160	1.7	14.3	2.1	1.7	1.9	24.0	0
3	795	.013	.002	210	870	140	1.4	25.7	1.1	1.7	3.0	13.9	0
4	553	.020	.006	156	520	90	1.1	13.1	1.7	1.4	1.4	13.3	0
5	777	.025	0	228	940	180	1.1	13.7	1.3	1.9	3.0	12.6	0
6	554	.015	.017	116	530	70	0.1	6.9	0.7	1.2	0	12.6	0
7	464	.025	.004	945	120	30	---	6.8	0.3	0.4	0.1	9.3	0
8	499	.020	.003	54	150	40	0.3	3.8	0.5	0.4	1.0	5.0	0

TABLE A-30. ACID PRODUCTION DURING 1ST CYCLE FERMENTATION
OF CUCUMBERS USING FRESH CONTROL BRINE--1976 DATA.
RESULTS ARE EXPRESSED AS PERCENT TITRATABLE ACIDITY
CALCULATED AS LACTIC ACID

Fermentation time (days)	Tank number							
	M50	M7	M47	M46	M6	M43	M9	M8
1	---	---	---	.02	.02	---	---	---
2	.01	.05	.02	.05	.06	.02	.05	.04
3	.04	.05	.02	.03	.16	.04	.07	.14
4	---	---	.04	.05	.24	.05	.10	.23
5	.13	.16	.06	.10	.29	.22	---	.31
6	.17	.23	.21	.18	.34	.07	.37	.34
7	.24	.30	.25	.29	.43	.16	.37	---
8	.29	.39	.29	.36	.54	.21	.47	---
9	.33	.39	.32	.42	.64	.25	.56	.47
10	.42	.49	.36	.46	.76	---	.62	.61
11	.45	.50	.38	.52	.77	.40	---	.64
12	.50	.54	.50	.54	---	.40	---	.66
13	.51	.58	.55	.56	.83	.44	.51	.66
14	.50	.63	.60	.67	.78	.27	.68	---
15	.60	.69	.62	---	.83	.34	.79	---
16	.55	.68	.64	.72	---	---	.78	---
17	.65	.70	.76	.65	---	.61	.80	.77
18	.68	.75	.68	---	.82	.58	---	.75
19	.70	.74	.71	.66	.84	.61	---	.70
20	.66	.78	.75	---	.92	.65	---	---
21	.69	.83	---	---	.93	.65	.87	---
22	.63	.75	.85	.63	.91	---	.84	---

TABLE A-31. ACID PRODUCTION DURING 1ST CYCLE FERMENTATION
OF CUCUMBERS USING FRESH CONTROL BRINE--1975 DATA.
RESULTS ARE EXPRESSED AS PERCENT TITRATABLE ACIDITY
CALCULATED AS LACTIC ACID

Fermentation time (days)	Tank number									
	L36	M2	M51	M1	M52	M9	M42	M35	M33	L48
1										
2	.03	.03	.06	.03	.03	.06	.03	.03	.03	.03
3	.15	.09	.12	.06	.06	.18	.09	.03	.18	.06
4	.27	.15	.18	.09	.21	.57	.24	.24	.27	.09
5	---	.24	.54	.18	.36	.54	.30	.33	.12	.09
6	.48	.27	.45	.21	.57	.57	.45	.36	.18	.12
7	.57	.45	.51	.36	.60	.57	.54	.45	.24	.21
8	.57	.48	.54	.46	.54	.60	.42	.57	.33	.36
9	.63	.54	.60	.33	.60	.66	.39	.48	---	---
10	.63	.60	.66	.42	.63	.63	.42	---	.42	---
11	.60	.66	.63	.51	.63	.69	.57	.57	.48	.54
12	---	.78	.62	.57	.63	.78	.54	.63	.54	.63
13	.81	.60	.75	.57	.69	.78	.63	.57	.60	.66
14	.84	.66	.75	.63	.78	.81	.63	.60	.63	---
15	.90	.72	.75	.69	.78	.78	.63	.63	.63	---
16	.87	.78	.78	.75	.81	.81	.54	.66	.69	---
17	.87	.63	.78	.69	.78	.81	.78	.63	---	---
18	.90	.81	.66	.72	.78	.90	.75	---	---	.81
19	.96	.84	.78	.63	.81	.87	.75	---	.72	.72
20	.93	.78	.81	.69	.87	.81	.78	.69	.78	.69
21	1.02	.69	.69	.75	.87	.93	.69	.72	.78	.69
22	.96	.78	.72	.60	.81	.84	.63	.72	---	---

TABLE A-32. ACID PRODUCTION DURING 2ND CYCLE FERMENTATION
OF CUCUMBERS USING 1ST CYCLE HEAT TREATED BRINE--1975 DATA.
RESULTS ARE EXPRESSED AS PERCENT TITRATABLE ACIDITY
CALCULATED AS LACTIC ACID

Fermentation time (days)	Tank number										
	L37	M3	M49	M47	M5	M7	M10	M41	M11	M8	L46
1											
2	.30	.12	.24	.21	.18	.18	.06	.09	.06	.03	.06
3	.18	.18	.21	.24	.21	.15	.12	.12	.06	.30	.09
4	.33	.21	.45	.33	.36	.39	.42	.24	.27	.15	.12
5	.54	.36	.45	.57	.48	.60	.54	.39	.42	.30	.21
6	.60	.81	.57	.45	.57	.63	.63	.42	.48	---	.30
7	.60	.51	.66	.57	.66	.69	.69	.48	.57	.54	.42
8	.72	.66	.75	.63	.69	.75	.75	.54	.57	.57	.54
9	.75	.75	.78	.60	.75	.81	.72	.57	.63	.54	---
10	.75	.78	.90	.48	.84	.75	.72	---	---	.60	---
11	---	.81	.87	---	.81	.78	.90	.63	.72	.81	.63
12	.81	.87	.93	.78	.81	.87	.84	.66	.72	.69	.72
13	.84	.87	.90	.78	.87	.72	.84	.54	.78	.75	.75
14	.93	.96	.96	.81	.84	.72	.84	.60	.63	---	---
15	.87	.96	1.02	.81	.84	.75	.90	.54	.81	---	---
16	.90	.99	1.02	.87	.84	.75	.90	.57	.81	.78	---
17	.96	.99	.99	.81	.87	.69	.99	.63	.78	.75	---
18	.93	1.02	1.05	.84	.87	.75	.96	---	---	.84	---
19	.90	1.02	.96	.72	.96	.78	.90	---	---	---	.81
20	1.02	1.05	.87	.84	.87	.72	.99	.33	.81	---	.87
21	.99	1.11	.93	.90	.84	.84	.93	.39	.87	---	.84
22	1.02	1.08	.87	.78	.99	.75	.96	.48	.75	---	---

TABLE A-33. ACID PRODUCTION DURING 2ND CYCLE FERMENTATION
OF CUCUMBERS USING 1ST CYCLE CHEMICAL TREATED BRINE--
1975 DATA. RESULTS ARE EXPRESSED AS PERCENT TITRATABLE
ACIDITY CALCULATED AS LACTIC ACID

Fermentation time (days)	Tank number									
	L44	M4	M50	M48	M6	M43	M40	M39	M45	L47
1										
2	.24	.30	.39	.15	.09	.12	.06	.06	.09	.18
3	.33	.39	.12	.12	.18	.24	.06	.06	.09	.21
4	.51	.42	.24	.21	.60	.54	.24	.33	.09	.33
5	---	.51	.30	.42	.63	.75	.33	.42	.18	.48
6	.69	.60	.54	.36	.78	.60	.27	.48	---	.54
7	.75	.60	.69	.66	.87	.69	.39	.33	.36	.60
8	.71	.66	.72	.75	.87	.72	.39	.33	.57	.69
9	.87	.75	.75	.81	.93	.69	.42	.54	.54	---
10	.81	.78	.81	.90	.99	.78	---	---	.60	---
11	.87	.81	.75	.96	.96	.90	.51	.63	.66	.84
12	---	.87	.84	.99	.93	.81	.54	.69	.66	.90
13	.96	.84	.90	1.02	.96	.93	.60	.57	.54	.93
14	1.05	.90	.90	.99	1.05	.93	.63	.63	---	---
15	1.23	.93	.99	1.05	.96	.93	.66	.75	---	---
16	.99	.96	1.05	1.08	.99	.90	.69	.78	.75	---
17	.99	1.02	.96	1.11	.96	.99	.66	.78	.81	---
18	1.05	.99	1.02	1.14	.96	.99	---	---	.84	.96
19	1.05	1.02	1.02	1.05	.99	.87	---	---	---	.99
20	1.02	1.05	.96	1.08	1.08	.84	.60	.75	---	1.05
21	1.08	.96	.99	1.17	.99	.96	.69	.84	---	.99
22	1.08	1.05	.99	1.05	.81	.93	.75	.84	---	---

TABLE A-34. ACID PRODUCTION DURING 3RD CYCLE FERMENTATION
OF CUCUMBERS USING 2ND CYCLE HEAT TREATED BRINE--1976 DATA.
RESULTS ARE EXPRESSED AS PERCENT TITRATABLE ACIDITY
CALCULATED AS LACTIC ACID

Fermentation time (days)	Tank number							
	M52	M1	M3	M44	M49	M42	M4	L48
1	---	.24	---	.12	.13	---	---	---
2	.26	.23	.16	.14	.19	.16	.13	.15
3	.23	---	.15	.12	.34	.17	.13	.30
4	---	---	.16	.08	.46	.17	.15	.44
5	.29	.49	.26	.28	.56	.26	---	.48
6	.43	.61	.41	.32	.61	.31	.41	.57
7	.53	.61	.49	.38	.70	.36	.49	---
8	.59	.64	.60	.44	.70	.37	.49	---
9	.69	.67	.62	.50	.86	.42	.59	.84
10	.74	.73	.64	.60	---	---	.62	.87
11	.73	.72	.76	.65	.91	.63	---	.95
12	.77	.74	.79	.70	.97	.59	---	.92
13	.81	.77	.79	.69	.96	.66	.73	.97
14	.79	.78	.89	.75	.69	.49	.76	---
15	.84	.84	.91	.85	.80	.60	.82	---
16	.84	.85	.84	.80	---	---	.84	---
17	.88	.83	.90	---	---	---	.83	1.01
18	.90	.85	.73	.71	.87	.63	---	---
19	.91	.83	.84	---	.87	.64	---	1.03

TABLE A-35. ACID PRODUCTION DURING 3RD CYCLE FERMENTATION
OF CUCUMBERS USING 2ND CYCLE CHEMICAL TREATED BRINE--
1976 DATA. RESULTS ARE EXPRESSED AS PERCENT TITRATABLE
ACIDITY CALCULATED AS LACTIC ACID

Fermentation time (days)	Tank number							
	M51	M2	M48	M45	M5	M41	M11	L47
1	---	.25	---	.15	.12	.12	---	---
2	.23	.24	.20	.09	.19	.09	.12	.21
3	.23	---	.17	.14	.38	.15	.13	.35
4	---	.41	.18	.07	.56	.34	.16	.48
5	.30	.54	.16	.23	.66	.36	---	.63
6	.45	.61	.33	.36	.73	.42	.46	.63
7	.54	.75	.42	.49	.79	.46	.47	.82
8	.64	.79	.51	.58	.80	.50	.56	.79
9	.69	.85	.55	.67	.91	---	.63	.91
10	.80	---	.61	.70	---	.75	.71	.88
11	.78	.93	.70	.71	1.04	.78	.81	.91
12	.82	.99	.75	.61	1.13	.78	.88	---
13	.84	1.01	.81	.73	1.06	.62	.98	---
14	.88	1.06	.80	.80	1.10	.69	.97	---
15	.87	1.07	.89	---	1.11	.67	1.03	.88
16	.78	1.08	.88	.91	---	.77	---	.82
17	.80	1.10	.98	.80	---	.90	---	.91
18	.83	1.08	.93	---	1.11	.82	---	---
19	.89	1.06	.91	.81	1.11	.86	1.02	---

TABLE A-36. INSTRON PRESSURE TEST ON 2ND CYCLE SALT STOCK
CUCUMBERS AFTER DESALTING. RESULTS ARE EXPRESSED
AS kg OF FORCE REQUIRED TO PUNCTURE THE FRUIT WITH
A 5/16" DIAMETER PROBE

Group no.	Control	Heated brine	Chemically treated brine
1	6.07	8.28	8.88
2	8.67	7.98	8.92
3	4.77	8.75	7.35
4	8.63	8.86	8.40
5	8.80	7.87	7.62
6	9.19	8.67	----
7	7.65	8.85	7.61
8	8.60	8.64	9.04
9	8.84	9.24	9.60
10	----	7.55	7.40
11	8.09	7.08	8.48

TABLE A-37. SAMPLE CALCULATIONS FOR 1 BUSHEL CUCUMBER
SALTING (DESALTING*)

Item	Amount	
<u>Fermentation</u>	<u>lb Salt</u>	<u>Total lb</u>
lb salt in 3.2 gal cover brine at 25°S	1.84	----
lb salt required to maintain 25°S	3.46	----
<u>Storage</u>		
lb salt required to raise salt concentration to 45°S	4.60	9.90
<u>Untanking</u>		
lb salt remaining in 3.8 gal spent brine	4.09	----
lb salt in 1 bushel or 5.4 gal pickles	5.81	9.90
<u>Desalting</u>		
lb salt in desalted pickles	2.21	----
lb salt lost in process water	3.60	----
<u>Summary</u>	<u>No recycling</u>	<u>Recycling</u>
total lb salt to 45°S	9.90	9.90
lb salt in spent brine	4.09	4.09
lb salt in process water	3.60	3.60
lb salt in excess brine (after fermentation)	0.65	0.65
lb salt saved because of recycling	----	3.44
lb salt to waste treat	7.69	4.25

- *Basis:
1. Bushel occupies 6 gal volume
 2. 3.2 gal needed to cover 1 bushel
 3. 65 parts cucumbers, 35 parts brine by weight
 4. 10% shrinkage of pickle stock, thus 10% excess brine generation
 5. Stock stored at 45°S desalted to 18°S.

TABLE A-38. HEAT INACTIVATION OF FUNGAL PECTINASES AT pH 3.3
IN 12% NaCl, 0.6% LACTIC ACID AND 0.1% Ca⁺⁺ ION

Organism	Heating temperature (°C)	Heating time (sec)	Activity remaining (%)
<u>Penicillium janthinellum</u>	78	20	16.3
		24	1.9
		25	1.1
<u>Penicillium janthinellum</u>	75	30	11.2
		40	2.9
		40	2.8
		45	1.6
<u>Penicillium oxalicum</u>	70	30	32.7
		40	9.6
		45	3.2
		50	3.0
<u>Fusarium solani</u>	70	15	17.0
		17	6.0
		18	3.5
		20	1.5
<u>Fusarium oxysporum</u>	70	18	27.0
		20	9.0
		22	2.6
		23	1.5
<u>Alternaria tenuis</u>	65	20	51.1
		30	20.7
		45	4.6
		60	1.3
<u>Trichoderma viride</u>	65	30	22.7
		35	10.6
		40	8.4
		45	5.0

TABLE A-39. EFFECT OF pH ON INACTIVATION OF Penicillium
janthinellum PECTINASE AT 75°C

pH	Heating time (sec)	Activity remaining (%)
3.1	28	6.2
	30	4.1
	33	2.7
	35	1.8
3.3	25	19.0
	30	10.7
	35	6.6
	40	3.3
3.5	30	10.3
	35	6.5
	37	5.5
	40	4.4
	45	3.1
3.7	35	10.3
	40	6.9
	45	5.1
	50	3.6
4.0	35	27.9
	40	15.5
	45	8.2
4.5	30	15.5
	32	10.2
	35	4.3
4.7	25	33.3
	27	19.9
	30	7.7
	32	3.2
	35	1.4

Table A-40. EFFECT OF pH ON INACTIVATION OF Penicillium
janthinellum PECTINASE AT 78°C

pH	Heating time (sec)	Activity remaining (%)
3.3	20	16.3
	24	1.9
	25	1.1
3.5	20	23.0
	24	4.7
	26	2.0
3.7	20	16.3
	24	5.8
	25	4.0
	26	3.3
4.0	20	42.1
	23	19.7
	26	5.3
	28	1.8
4.5	20	32.1
	23	9.0
	25	5.3

TABLE A-41. EFFECT OF NaCl CONCENTRATION OF THE HEAT
INACTIVATION OF Penicillium janthinellum PECTINASE
AT 75°C

NaCl (%)	pH	Heating time (sec)	Activity remaining (%)
8	3.5	30	12.7
		35	5.0
		40	3.3
		45	1.7
12	3.5	30	10.3
		35	6.5
		37	5.5
		40	4.4
		45	3.1
16	3.5	30	32.3
		35	22.3
		40	15.5
		50	6.9
		60	3.4
8	3.7	30	10.7
		35	6.8
		40	4.8
		45	3.5
12	3.7	35	10.3
		40	6.9
		45	5.1
		50	3.6
16	3.7	30	37.8
		40	19.0
		50	11.4
		60	5.8
		70	3.1

TABLE A-42. HEAT INACTIVATION OF Penicillium janthinellum
PECTINASE IN 12.6% NaCl COMMERCIAL SPENT BRINE

Brine pH	Heating time (sec)	Activity remaining (%)
3.5	30	48.2
	40	9.4
	45	4.4
	50	1.9
3.7	30	25.4
	36	11.8
	45	3.5
	50	1.9

TABLE A-43. INACTIVATION OF PECTINASE FROM *Penicillium*
janthinellum AT HIGH pH IN SPENT BRINE. TEMPERATURE
 22°C (71.6°F). SALT CONCENTRATION 8.0%

pH	Incubation time (hr)	Activity remaining (%)
10.6	0	94.9
	1	79.4
	2	74.4
	3	83.9
	5	68.0
	8	64.8
	14	62.6
	23	46.8
	34	42.0
	47	49.0
	70	52.0
11.0	0	82.0
	1	65.7
	2	57.7
	4	41.9
	5	40.7
	7	34.3
	10	24.3
	15	15.0
	24	11.5
	36	9.9
11.2	48	8.0
	0	75.8
	3	16.1
	6	8.2
	22	5.8
	30	2.2
11.3	36	ND*
	0	81.6
	1	37.6
	2	16.3
	3	13.1
	4	12.2
	6	19.2
	9	8.0
	15	6.4
	24	1.6
	36	0.3
	48	0.6

(continued)

TABLE A-43 Continued

pH	Incubation time (hr)	Activity remaining (%)
11.6	0	59
	1	22
	3.5	6.1
	6.5	3.4
	22	ND*

*ND = Not detectable.

TABLE A-44. INACTIVATION OF Penicillium janthinellum
PECTINASE IN SIMULATED SPENT BRINE AT 10°C (50°F).
SALT CONCENTRATION 12%

pH	Incubation time (hr)	Activity remaining (%)
11.0	0	71.9
	6	69.8
	10	69.8
	21	63.3
	33	61.3
	45	59.7
	57	56.5
	69	51.6
11.7	0	70.1
	2	60.4
	9	65.3
	20	55.5
	30	53.5
	40	53.9